Tellegen Theorem based Load Flow Solution of Radial Distribution Network (Main feeder)

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***Abstract*— The Distribution systems are usually radial with high R/X ratio and the conventional load flow methods like Newton Raphson and Fast decoupled methods are proved to be inefficient in solving load flow of radial distribution system. The researchers have developed many separate load flow method based on conservation of power at a bus level and one such method is forward sweeping method. In this paper presented a Tellegen theorem based load flow solution of radial distribution network. The power conservation principle instead of at bus level, network level which is nothing but Tellegen theorem principle is considered and load flow technique has been developed. The proposed algorithm is demonstrated on a 440V, 12 bus radial distribution system with a main feeder and the results are compared with one such separate load flow method "forward sweeping method" and it is observed that the proposed method is has smaller execution time and less number of iterations.**

Keywords : Distribution system; load flow; Tellegen theorem

I. INTRODUCTION

Conventional load flow methods are unsuitable to provide reasonable solution due to radial structure and high r/x ratios of branches of distribution network. Majority of classical load flow methods have performance problems like non convergence, high memory requirement and large computation time.

K. Prakash [1] *et al* developed a power flow algorithm involving only diagonal elements of the Distribution Load Flow (DLF) matrix and storage was made in a single dimension vector and LU decomposition is eliminated. Narendra Kumar[2] *et al* utilised Forward sweep method for an iterative evaluation of node parameters of large structures and made the process competent, computationally fast irrespective of system characteristics. J.B.V.Subrahmanayam[3] *et al* a three phase load flow solution using topological characteristics and two special matrices .

In [4], an effective approach for unbalanced three phase distribution power flow solution is propoed. In [5], it presents an approach of power flow with a view to obtain a reliable convergence in distribution systems.

In [6], the load flow study of radial distribution with embedded generation has been carried out. In [7], it presents a new and accurate method for load−flow solution of radial distribution networks with minimum data preparation. In [8], it presents an adaptive distributed power flow solution method based on the compensation-based method. In [9], shows that the load flow problem of a radial distribution system can be modeled as a convex optimization problem, particularly a conic program. In [10] an attempt for load flow solution using Tellegen theorem has been dealt.

The Tellegen theorem is well proved theorem for power conservation of a network and the concept is used to develop a load flow study. The Tellegen theorem concept of power conservation at network level is a proper solution. The Tellegen theorem method of load flow study is used to determine the node voltage magnitudes as well as the line power losses for radial distribution network with main feeder and laterals. The objective equation developed using Tellegen theorem does not have either any higher order terms or any trignometric terms. Computation and memory requirements are very much reduced. Flat voltage profile assumption solved problems arose due to initial parameter assumption.

II PROBLEM FORMULATION

The distribution network configuration considered in this paper is a radial feeder. A load flow solution technique for radial distribution network using Tellegen theorem is presented. The principle of Tellegen theorem is used to develop the power flow equations. The power summation principle at a node is used to determine the power flowing through the terminal node. Node voltage angles are omitted, a simple linear equation for node voltage magnitude is derived.

The load flow study of the main feeder case is carried and the node voltage magnitudes of the main feeder are computed.. It is found that there is a large computational and storage economy is achieved. The bus voltage angles are omitted in the problem formulation because the radial loads use the voltage magnitude than phase angle.

Consider the distribution network with only a main feeder.

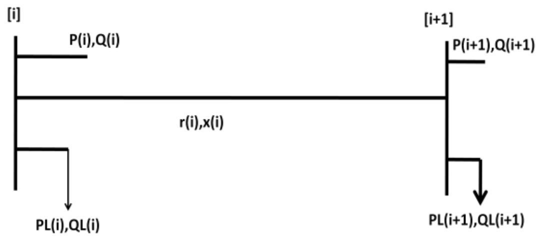

FIG 1 ELECTRICAL EQUIVALENT NETWORK

According to Tellegen theorem, " Sum of complex powers in a network is equal to zero",

$$\sum_{k=1}^{N_b} V_k I_k^{\ *} = 0 \tag{1}$$

which can be written as

$$-V(1)I(1)^* + (V(1)-V(2))I(1)^* + (P_L(1)+jQ_L(1)) + \ldots\ldots\ldots\ldots = 0 \tag{2}$$

The power injected into the network is given by

$$V(1)I(1)^* = NewPP + jNewQQ \tag{3}$$

The real and reactive power injected into the system is given by

$$NewPP = \sum_{i=1}^{N_b} \frac{(V(i)-V(i+1))^2}{r(i)^2 + x(i)^2} r(i) + \sum_{i=1}^{N_b} P_L(i) \tag{4}$$

$$NewQQ = \sum_{i=1}^{N_b} \frac{(V(i)-V(i+1))^2}{r(i)^2 + x(i)^2} x(i) + \sum_{i=1}^{N_b} Q_L(i) \tag{5}$$

OldPP and NewPP are real and reactive powers injected into the distribution system at the beginning of the iteration.

$$delP = NewPP - OldPP \tag{6}$$

$$delQ = NewQQ - OldQQ \tag{7}$$

The real and reactive powers flowing in the branch between i and i+1 buses are

$$P(i+1) = P(i) - R(i) - P_L(i) \tag{8}$$

$$Q(i+1) = Q(i) - X(i) - Q_L(i) \tag{9}$$

where

$$R(i) = \sum_{i=1}^{N_b} \frac{(V(i)-V(i+1))^2}{r(i)^2 + x(i)^2} r(i) \tag{10}$$

$$X(i) = \sum_{i=1}^{N_b} \frac{(V(i)-V(i+1))^2}{r(i)^2 + x(i)^2} x(i) \tag{11}$$

$$\frac{(V(i)-V(i+1))^2}{r(i)^2 + x(i)^2} = \frac{P(i)^2 + Q(i)^2}{V(i)^2} \tag{12}$$

The current flowing in the ith line is given by

$$V(i+1) = \frac{(V(i)xV(i) - k3)}{V(i)} \tag{13}$$

where $k3 = \sqrt{(P(i)^2 + Q(i)^2)(r(i)^2 + x(i)^2)}$ (14)

III Algorithm for the proposed method

Algorithm for the distribution network with main feeder using Tellegen theorem method

1.Read the feeder data i.e., resistance and reactance of the branch connected to the node, the connected load powers real and reactive, the source node voltage magnitude of the main feeder.

2.Read the number of laterals connected, the start node and end node of each lateral.

3.Load is lumped at respective node of each lateral. The main feeder case of the Distribution network

aRead substation voltage magnitude(1) , line data(r,x) and load data(P_L,Q_L).

b Assume a flat voltage profile

c Set OldPP, OldQQ to previous iteration real and reactive powers injected into the network to zero

d Compute new powers injected NewPP, NewQQ into the distribution network using the following equations (4) and (5).

e Compute the difference between (OldPP and NewPP) and (Old QQ and NewQQ) using equations (6) and (7).

f Check for DelPP and DelQQ less than the tolerance

g If the tolerance is not met, increment the

Bus no	R (ohms)	X (ohms)	PL (KW)	QL (KVAR)
1	1.093	0.455	00.00	00.00
2	1.184	0.484	60.00	60.00
3	2.095	0.873	40.00	30.00
4	3.188	1.328	55.00	55.00
5	1.093	0.455	30.00	30.00
6	1.002	0.417	20.00	15.00
7	4.403	1.215	55.00	55.00
8	5.642	1.597	45.00	45.00
9	2.89	0.818	40.00	40.00
10	1.514	0.488	35.00	30.00
11	1.238	0.351	40.00	20.00
12	-	-	15.00	15.00

iteration count

Bus no	Forward Sweeping method (existing method)	Tellegen theorem method (Proposed method)
1	1.00000	1.00000
2	0.99585	0.99629
3	0.99198	0.99284
4	0.98579	0.98731
5	0.97792	0.98029
6	0.97551	0.97815
7	0.97347	0.97633
8	0.96693	0.97054
9	0.96075	0.96509
10	0.95860	0.96320
11	0.95790	0.96260
12	0.95771	0.96242

h Set OldPP=NewPP and OldQQ=NewQQ

i The real and reactive powers injected and new node voltage magnitudes are calculated by using the equations (8), (9) and (13).

j If tolerance is met, print the results

IV RESULTS AND DISCUSSION

The line and load data of 12 node, 440V radial distribution system data is given in the Table 1. The load flow solution results based on Tellegen theorem and Forward Sweeping method are given in Table 2,3 and 4.

TABLE 1

TABLE 2

TABLE 3

Method	Total Real power losses (KW)	Total Reactive power losses (KW)
Forward Sweeping method	10.01	5.85
Tellegen theorem method	12.52	4.85

TABLE 4

Method	Number of iterations taken to converge
Forward Sweeping method	20
Tellegen theorem method	05

V CONCLUSION

In this paper, the algorithm for load flow solution of radial distribution network using Tellegen theorem has been developed. A 12 node 440 V radial distribution system with main feeder is taken as test data. Results for load flow solution using Tellegen theorem and forward sweeping methods are shown in the tables. The results indicate that Tellegen theorem converges faster than forward sweeping method. Computation and storage economy are achieved using Tellegen theorem based load flow solution.

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