Load Flow Analysis on Distribution Networks Integrating Microsources

R. S. Syed Mohammed[1] A. Azeezur Rahman[2] S. Siddik[3]
[1]PG Scholar [2]Assistant Professor [3]Ph.D Scholar
[1,2]Sri Muthukumaran Institute of Technology, Chennai [3]College of Engineering Anna University, Chennai

Abstract— Electricity distribution is the eventual stage in the delivery of electricity to the end consumers. A distribution system's network which carries electricity from the transmission system and delivers it to consumers. There are two types os distribution network , radial or interconnected. An interconnected network is generally found in more down town areas and will have numerous connections to other points of supply. These points of contact are normally open but allow various composition by the operating utility by closing and opening of switches. In distribution systems, the voltages at buses reduces when carried away from the substation, also the losing is high. The logic for decrease in voltage and high losses is the deficient amount of reactive power, which can be furnished by the shunt capacitors. The work proclaimed in this thesis is carried out with the objective of identifying the flawless locations and sizes of shunt capacitors and DGs to be placed in radial distribution system to have overall economy considering the saving due to energy loss cut down .The load flow of pre compensated distribution system is carried out at first stage. On the basis of load flow solutions, loss sensitivity factors (LSF) indicating the likely locations for compensation are computed. From LSF, the candidate number of buses is spotted. To diagnose the sizes of the capacitor for curtailing the energy losses. The contrasting method is tested for distribution systems at 11 KV voltage distribution system while taking the different sizes for capacitors and DGs.

Key words: DGs, LSF

I. INTRODUCTION

A. Overview of Distribution Network:

The load flow of a distributed network provides the steady state solution of various parameters like voltages, currents and losses to be calculated. The power flow is important for the analysis of distribution system, to investigate the issues related to planning, design, operation and control. Application like optimal capacitor placement in distribution and distribution automation system, requires repeated load flow solution.

1) Line losses:

The losses in hvdc for distribution system of same power are less than the of LV line. Thus, the losses in LV network are negligible bringing down the total energy losses considerably

2) Voltage Drop:

The voltage drop for distribution of same power is less than that of LVDS and ensures proper voltage profile at consumer points.

3) Power Factor Improvement:

The single phase motors have built in capacitors and pf is more than 0.95. the higher pf causes low energy losses and better voltage profile

4) End User's Equipments:

Due to better voltage profile, the efficiency of end user's equipment is high, bringing in considerable benefit by way of energy conservation.

5) Reliability of Supply:

The voltage drop or fluctuation occurring can be remedied by installations of DVR, thus the reliability of supply is high. Many methods such gauss sediel, Newton raphson are well reported to carry the load flow of transmission system. The use of these methods for distribution system may not be advantageous because they are mostly based on general meshed topology of typical transmission system where as most distribution systems have a radial or tree, structure. Further distribution system posses high R/X ratio. Which cause the distribution systems to be ill conditioned for conventional load flow methods

The characteristics of electric distribution systems are

1) Radial or weakly meshed structure
2) Unbalanced operation and distributed loads
3) Large number of buses and branches
4) It has wide range of resistance and reactance values
5) Distribution system has multiphase operation

The efficiency of the problem of distribution system depends on the load flow algorithm because load flow solution has to run for many times. Therefore, the load flow solution of distribution system should have robust and time efficient characteristics. A method which can find the load flow solution of radial distribution system directly by using topological characteristic of distribution network is used. In this method, the formulation of time consuming Jacobian matrix or admittance matrix, which is required in conventional methods, is avoided.

B. Voltage Distribution System:

The existing rural distribution system in India consists of largely 3 phase 11 KV main distribution feeders with 3 phase spur lines and 11/0.4 KV three phase distribution transformers. The distribution system on low voltage side is done by 3 phase 4 wire, 3 phase 5 wire, single phase 3 wire, and single phase 2 wire LT lines. This system involves nearly 2:1 ratio of LV and HV line lengths. Large LT network results in high occurrence of LT faults leading to frequent interruptions in supply and high incidence of distribution transformer failures due to LT fault currents.

Due to use of smaller rating transformers, either 3 phase or single phase length of LT lines is considerably reduced and power is distributed mainly through HV (11 KV) lines. Distribution system employs a suitable mix of 11 KV 3 phase and single phase or 3 phase configuration for giving supply either to small rating lines. With the main line being 3 phase, the spur line comprises of either single phase or three phase configuration for giving supply to small rating single phase or three phase distribution transformers

C. Elements of the Distribution System:

In general, the distribution system is derived from electrical system which is Substationally fed by the consumers' premises and the transmission system. It generally consists of feeders, laterals (circuit-breakers) and the service mains.

1) Distributed Feeders:

A feeder is a conductor, which connects the sub-station (or localized generating station) to the area where power is to be distributed. Generally, no tapping are taken from the feeder so that the current in it remains the same throughout. The main consideration in the design of a feeder is the current carrying capacity.

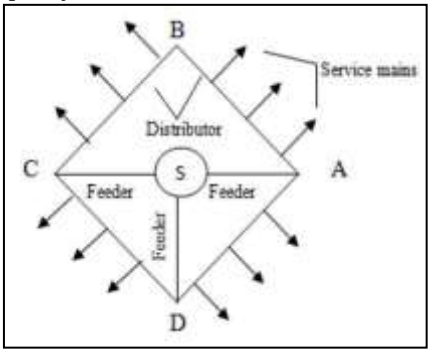

Fig. 1: Elements of Distribution System

– Distributor

A distributor is a conductor from which tapping are taken for supply to the consumers. In Figure1.2, AB, BC, CD, and DA are the distributors. The current through a distributor is not constant because tapping are taken at various places along its length. While designing a distributor, voltage drop along its length is main consideration since the statutory limit of voltage variations is 10% of rated value at the consumer's terminals.

2) Service Mains:

A service mains is generally a small cable which connects the distributor to the consumer's terminals.

3) Requirements of a Distribution System:

It is mandatory to maintain the supply of electrical power within the requirements of many types of consumers. Following are the necessary requirements of a good distribution system:

a) Availability of Power Demand:

Power should be made available to the consumers in large amount as per their requirement. This is very important requirement of a distribution system.

b) Reliability:

As we can see that present day industry is now totally dependent on electrical power for its operation. So, there is an urgent need of a reliable service. If by chance, there is a power failure, it should be for the minimum possible time at every cost. Improvement in reliability can be made upto a considerable extent by

1) Reliable automatic control system.
2) Providing additional reserve facilities.

c) Proper Voltage:

Furthermost requirement of a distribution system is that the voltage variations at the consumer terminals should be as low as possible. The main cause of changes in voltage variation is variation of load on distribution side which has to be reduced. Thus, a distribution system is said to be only good, if it ensures that the voltage variations are within permissible limits at consumer terminals.

d) Loading:

The transmission line should never be over loaded and under loaded.

e) Efficiency:

The efficiency of transmission lines should be maximum say about 90%.

D. Features of RDN:

1) Uncertainties and Imperfection of network parameters.
2) High R/X ratio
3) Extremely large number of nodes and branches.
4) Dynamic change in imposed load.

E. Ring Main System:

The loop (or ring) distribution system is one that starts at a distribution substation, runs through or around an area serving one or more distribution transformers or load centre, and returns to the same substation.

The ring main system has the following advantages:

1) There are very less voltage fluctuations at consumer's terminals.
2) The system is very reliable as each distributor is fed with two feeders. In case, of fault in any section of feeder, the continuity of supply is maintained.

F. Distribution System Load Flow:

1) Load Flow of Distribution System:

The method to carry out the load flow for distribution system under balanced operating condition employing constant power load model can be under stood through the following points:

1) Equivalent current injection.
2) Formulation of BIBC matrix.
3) Formulation of BCBV matrix.

a) Equivalent Circuit Injection:

The method is based on the equivalent current injection. At bus i, the complex Power Si is specified and the corresponding equivalent current injection at the K-th iteration of the solution is computed as

$$S_i = P_i + jQ_i \qquad i=1,2,3,....N \qquad (4.1)$$

$$I_i^k = I_i^r * V_i^k + j * I_i^k * V_i^k = \frac{P_i + jQ_i}{V_i^k} \qquad (4.2)$$

Where S_i is the complex power at the i^{th} bus
P_i is the real power at the i^{th} bus
Q_i is the reactive power of i^{th} bus
Vi (k) is the bus voltage at the *k*-th iteration for i-th bus
Ii (k) is the equivalent current injection at the *k*-th iteration for i-th bus.
I(r) and I(i) are the real and imaginary parts of the equivalent current injection at the *k* iteration for i-th bus

2) Formation of BIBC Matrix:

The formulation of Bus-injection to Branch-current (BIBC) matrix is explained with the help of simple distribution system

The power injections at each bus can be converted into the equivalent current injections using eq. and a set of equations can be written by applying Kirchhoff's Current Law (KCL) at each bus. Then, the branch currents can be formed as a function of the equivalent current injections. As shown in Fig6.1. , the branch currents B5, B4, B3, B2 and B1 can be expressed as

$B_5=I_6$
$B_4=I_5$
$B_3=I_4+ I_5$
$B_2= I_3+ I_4+ I_5+ I_6$
$B_2= I_2+ I_3+ I_4+ I_5+ I_6$ (4.3)

From the above equation of BIBC matrix can be obtained

$$\begin{pmatrix} B_1 \\ B_2 \\ B_3 \\ B_4 \\ B_5 \end{pmatrix} = \begin{pmatrix} 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 & 1 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \\ I_5 \end{pmatrix}$$

The BIBC matrix can be obtained as from the general eq

[B]=[BIBC] [I] (4.4)

The following steps are used to form BIBC matrix

1) Step 1:
   For a system with m branch sections and an n-bus, the dimension of the BIBC matrix is m × (n– 1).
2) Step 2:
   If a line section (B) is located between Bus i and Bus j, copy the k column of the i-th bus of BIBC matrix to the column of the j-th bus and fill a + 1 in the position of the k-th row and the j-th bus column.
3) Step 3:
   Go to step 2 until all the line sections are included in the BIBC matrix.

3) Formation of BCBV matrix:

The Branch-Current to Bus voltage (BCBV) matrix summarizes the relation between branch current and bus voltages. The relations between the branch currents and bus voltages can be obtained easily. As shown in Fig. 6.1, the voltages of Bus 2, 3, and 4 are expressed as

$$V_2 = V_1 - B_1 Z_{12}$$
$$V_3 = V_2 - B_2 Z_{23}$$
$$V_4 = V_3 - B_3 Z_{34}$$

Substituting eqs. (6.10) and (6.11) into eq. (6.12), the voltage of Bus 4 can be rewritten as

$$V_4 = V_1 - B_1 Z_{12} - B_2 Z_{23} - B_3 Z_{34} \quad (4.5)$$

From eq, it can be seen that the bus voltage can be expressed as a function of the branch currents, line parameters and substation voltage. Similar procedures can be utilized for other buses, and the Branch-Current to Bus-Voltage (BCBV) matrix can be derived as

$$\begin{pmatrix} V_1 \\ V_1 \\ V_1 \\ V_1 \\ V_1 \end{pmatrix} - \begin{pmatrix} V_2 \\ V_3 \\ V_4 \\ V_5 \\ V_6 \end{pmatrix} = \begin{pmatrix} Z_{12} & 0 & 0 & 0 & 0 \\ Z_{12} & Z_{23} & 0 & 0 & 0 \\ Z_{12} & Z_{23} & Z_{34} & 0 & 0 \\ Z_{12} & Z_{23} & Z_{34} & 0 & 0 \\ Z_{12} & Z_{23} & 0 & 0 & Z_{36} \end{pmatrix} \begin{pmatrix} B_1 \\ B_2 \\ B_3 \\ B_4 \\ B_5 \end{pmatrix}$$

The general form can be expressed as

$$[\Delta V] = [BCBV] * [B] \quad (4.6)$$

The following steps are used to form BIBC matrix

1) Setp 1: For a system with m branch sections and n bus, the dimension of BCBV matrix is (n-1)xm.
2) Step 2: If a line section (B) is located between Bus i and Bus j, copy the row k of the i-th bus of the BCBV matrix to the row of the j-th bus, and fill the line impedance (Z) in the position of j-th bus row and the k-th ij column.
3) Step 3: Repeat Step (2) until all the line sections are included in the BCBV matrix.

It can be seen that the algorithms for the BIBC and BCBV matrices are almost similar. The only difference in the formation of BIBC matrix and BCBV matrix is that, in BIBC matrix i-th bus column is copied to the column of the j-th bus and fill with +1 in the k-th row and the j-th bus column, while in BCBV matrix row of the i-th bus is copied to the row of the j-th bus and fill the line impedance (Zij) in the position of the j-th bus row and the k-th column The formation of BIBC and BCBV matrices .These matrices explore the topological structure of distribution systems. The BIBC matrix is responsible for the relations between the bus current injections and branch currents. The corresponding variation of the branch currents, which is generated by the variation at the current injection buses, can be found directly by using the BIBC matrix. The BCBV matrix is responsible for the relations between the branch currents and bus voltages. The corresponding variation of the bus voltages, which is generated by the variation of the branch currents, can be found directly by using the BCBV matrix. Combining eqs. (4.9) and (4.12), the relations between the bus current injections and bus voltages can be expressed as:

B]=[BIBC] [I] (4.9)

$$[\Delta V] = [BCBV] * [B] \quad (4.10)$$

$$[\Delta V] = [BCBV] * [BIBC][I] \quad (4.11)$$

[DLF]=[BCBV]*[BIBC] (4.12)

$$[\Delta V] = [DLF][I] \quad (4.13)$$

G. Loss Sensitive Factor and Capacitor Placement:

1) Loss Sensitive Factor

To identify the location for capacitor placement in distribution system Loss Sensitivity Factors have been used. The loss sensitivity factor describes the maximum loss reduction in a particular bus when the capacitor is placed. Therefore these sensitive buses can be used as candidate buses for the capacitor placement. As only few buses can be candidate buses for compensation, the installation cost on capacitors is reduced.

2) Bus Selection

The values of loss sensitivity factors have been arranged in descending order and correspondingly the bus numbers are stored in bus position 'bpos[i]' vector. The descending order will decide the sequence in which the buses are to considered for compensation. At these buses of 'bpos [i]' vector, normalized voltage magnitudes are calculated by considering the base case voltage magnitudes given as below:

$$norm[i] = |V[i]|/0.95 \quad (4.14)$$

The 'norm[i]' decides whether the buses need reactive compensation or not. The buses whose norm[i] value is less than 1.01 can be selected as the candidate buses for capacitor placement. The following are the steps to be performed to find out the potential buses for capacitor placement:

1) Step 1: Calculate the Loss Sensitivity Factor at the buses of distribution system
2) Step 2: Arrange the value of Loss Sensitivity Factor in descending order. Also store the respective buses into bus position vector bpos[i].
3) Step 3: Calculate the normalized voltage magnitude norm[i] of the buses of bpos[i]
4) Step 4: The buses whose norm[i] is less than 1.01 are selected as candidate buses for capacitor placement.

3) Capacitor Placement:

Capacitors have been commonly used to provide reactive power in distribution systems. The capacitor placement problem consists of determining the optimal numbers, types, locations and sizes of capacitor banks. The capacitor banks are placed in a real power network for the purpose of economic minimization of loss and enhancement of voltage.

Distribution system provides a final link between the high voltage transmission system and the consumers. To improve the overall efficiency of power system, the performance of distribution system must be improved. An important method of controlling bus voltage is by shunt capacitor banks at the buses at both transmission and distribution levels along lines or substation and loads

The problem of capacitor allocation in electric distribution systems involves maximizing "energy and peak power (demand) loss reductions" by means of capacitor installations. As a result power factor of distribution system improves. A non linear portion of the loads has increased significantly. Harmonic current injected by these loads into the distribution system should be considered during capacitor placement.

II. COMPARISON STUDY

The line data and load data of 11kV, 33 bus, 4 lateral radial distribution system feeder (Base voltage =11kV, Base MVA=100MVA) are shown in the appendix

A. Case 1: Load flow of Normal 33 bus radial distribution network

In this case voltage at the buses are violated between 1 pu to 0.8820 pu which is not sustainable minimum limits. Total real and reactive power losses are 2281.5877KW and 182.3058KVAr per unit respectively without shunt capacitors or DVR. The test system is a 33 node radial distribution system which one main feeder and three laterals are shown in Fig. 4.1

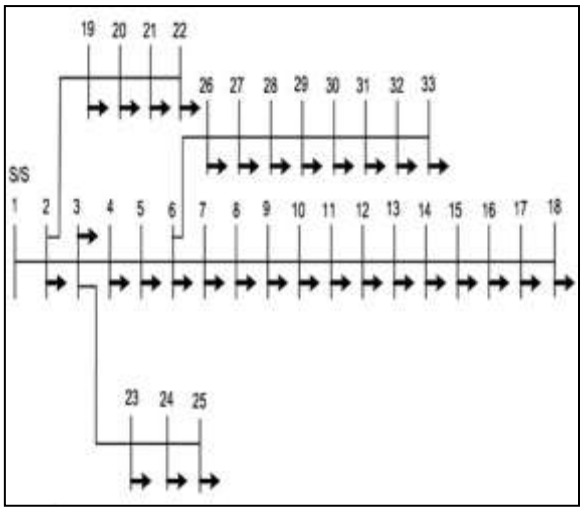

Fig. 2: IEEE 33 Bus Radial Distribution Systems

B. Case 2: Placement of capacitors in locations

Busses are 7, 12, 28 ,29, 30 and the capacitors values are150, 350, 250,300,750 VAr Using sensitivity analysis the optimal location was identified in an IEEE 33 bus system and total active and reactive power losses are calculated as 187.9595KW and 122.3871KVAr

C. Case 3: Load flow of Normal 69 bus radial distribution network:

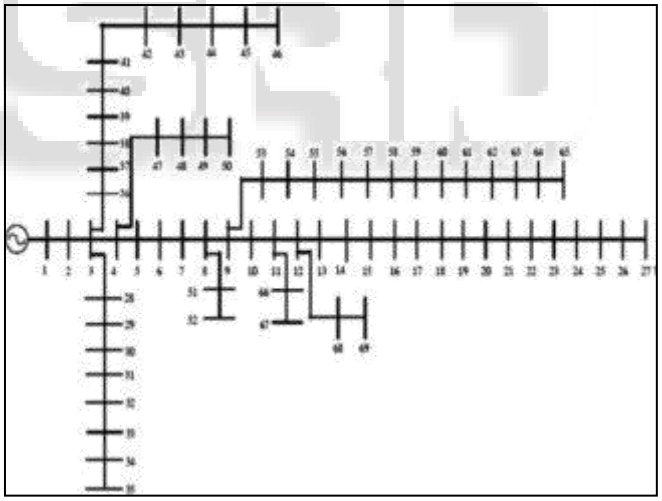

Fig. 3: Normal 69 Bus Radial Distribution Network

III. VERIFICATION AND RESULTS

A. Line Data for 33bus system:

s.no	From Bus	To Bus	R	X
1	1	2	0.0922	0.0470
2	2	3	0.4930	0.2511
3	3	4	0.3660	0.1864
4	4	5	0.3811	0.1941
5	5	6	0.8190	0.7070
6	6	7	0.1872	0.6188
7	7	8	0.7114	0.2351
8	8	9	1.0300	0.7400
9	9	10	1.0440	0.7400
10	10	11	0.1996	0.0650

11	11	12	0.3744	0.1238
12	12	13	1.4680	0.1550
13	13	14	0.5416	0.7129
14	14	15	0.5910	0.5260
15	15	16	0.7463	0.5450
16	16	17	1.2890	1.7210
17	17	18	0.7320	0.5740
18	18	19	0.1640	0.1565
19	19	20	1.5042	0.3554
20	20	21	0.4095	0.4784
21	21	22	0.7089	0.9373
22	22	23	0.4512	0.3083
23	23	24	0.8980	0.7091
24	24	25	0.8960	0.7011
25	25	26	0.2030	0.1034
26	26	27	0.2842	0.1447
27	27	28	1.0590	0.9337
28	28	29	0.8042	0.7006
29	29	30	0.5075	0.2585
30	30	31	0.9744	0.9630
31	31	32	0.3105	0.3619
32	32	33	0.3410	0.5302

Table 1: Line Data for 33bus System

B. Bus Data for 33 Bus System:

FB	TB	P	Q
1	0	0	0
2	100	60	0
3	90	40	0
4	120	80	0
5	60	30	0
6	60	20	0
7	200	100	0
8	200	100	0
9	60	20	0
10	60	20	0
11	45	30	0
12	60	35	0
13	60	35	0
14	120	80	0
15	60	10	0
16	60	20	0
17	60	20	0
18	90	40	0
19	90	40	0
20	90	40	0
21	90	40	0
22	90	40	0
23	90	50	0
24	420	200	0
25	420	200	0
26	60	25	0
27	60	25	0
28	60	20	0
29	120	70	0
30	200	600	0
31	150	70	0
32	210	100	0
33	60	40	0

Table 2: Bus Data for 33 Bus System

C. Load Flow on Distributed System:

A graph is plotted for ploss and qloss

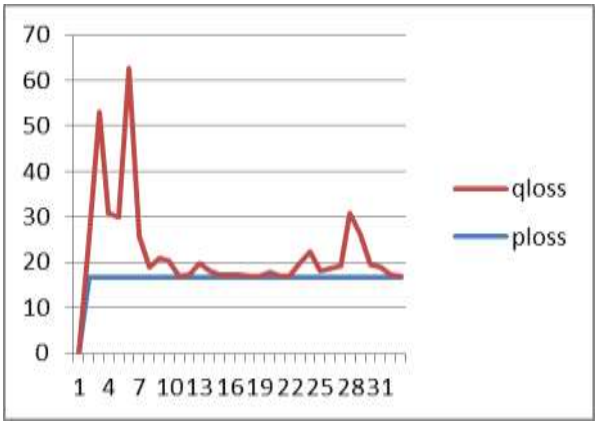

Fig. 4: A graph is plotted for ploss and qloss

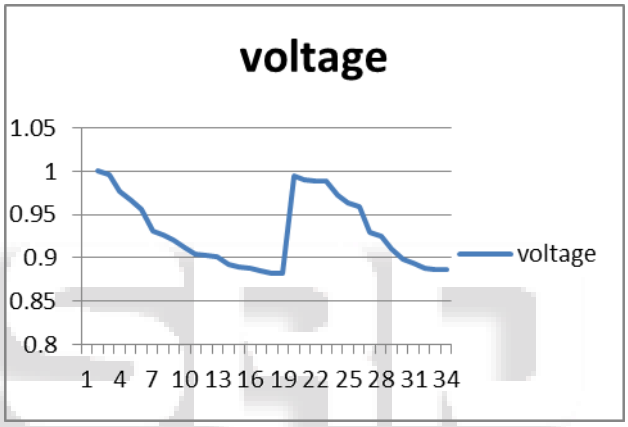

Fig. 5: A graph is plotted for ploss and qloss

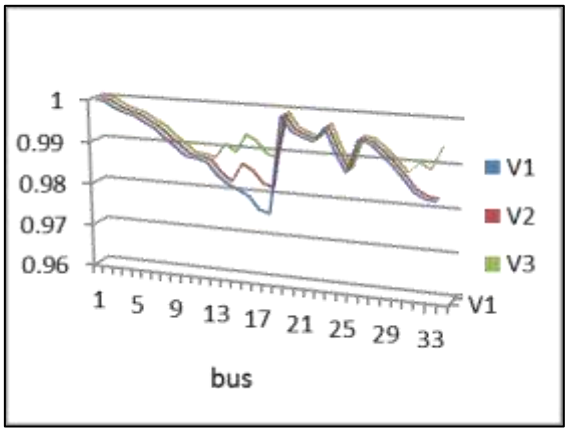

Fig. 6:

Line data for 69 bus system

System data for 69-bus radial distribution network('*' denotes a tie-line)

Branch Number	Sending Bus	Receiving Bus	Resistance	Reactance	Nominal Load at receiving bus		Maximum Line Capacity (kVA)
					P (kW)	Q (kVAr)	
1	1	2	0.0005	0.0012	0.0	0.0	10761
2	2	3	0.0005	0.0012	0.0	0.0	10761
3	3	4	0.0015	0.0036	0.0	0.0	10760
4	4	5	0.0251	0.0294	0.0	0.0	5823
5	5	6	0.3660	0.1864	2.60	2.20	1899
6	6	7	0.3811	0.1941	40.40	30.00	1899
7	7	8	0.0922	0.4770	75.00	54.00	1899
8	8	9	0.0493	0.0251	30.00	22.00	1899
9	9	10	0.8190	0.2707	28.00	19.00	1455
10	10	11	0.1872	0.0619	145.00	104.00	1455
11	11	12	0.7114	0.2351	145.00	104.00	1455
12	12	13	1.0300	0.3400	8.0	5	1455
13	13	14	1.0440	0.3450	8.0	5.50	1455
14	14	15	1.0580	0.3496	0.0	0.0	1455
15	15	16	0.1966	0.0650	45.50	30.00	1455
16	16	17	0.3744	0.1238	60	35.00	1455
17	17	18	0.0047	0.0016	60	35.00	2200
18	18	19	0.3276	0.1083	0.0	0.0	1455
19	19	20	0.2106	0.0690	1.0	0.60	1455
20	20	21	0.3416	0.1129	114.00	81.00	1455
21	21	22	0.0140	0.0046	5.0	3.50	1455
22	22	23	0.1591	0.0526	0.0	0.0	1455
23	23	24	0.3463	0.1145	28.00	20.00	1455
24	24	25	0.7488	0.2475	0.0	0.0	1455
25	25	26	0.3089	0.1021	14.00	10.00	1455
26	26	27	0.1732	0.0572	14.00	10.00	1455
27	27	28	0.0044	0.0108	26.00	18.60	10761
28	28	29	0.0640	0.1565	26.00	18.60	10761
29	29	30	0.3978	0.1315	0.0	0.0	1455
30	30	31	0.0702	0.0232	0.0	0.0	1455
31	31	32	0.3510	0.1160	0.0	0.0	1455
32	32	33	0.8390	0.2816	14.00	10	2200
33	33	34	1.7080	0.5646	9.5	14.00	1455
34	34	35	1.4740	0.4873	6.0	4.00	1455
35	35	36	0.0044	0.0108	26.00	18.55	10761
36	36	37	0.0640	0.1565	26.00	18.55	10761
37	37	38	0.1053	0.1230	0.0	0.0	5823
38	38	39	0.0304	0.0355	24.00	17.00	5823
39	39	40	0.0018	0.0021	24.00	17.00	5823
40	40	41	0.7283	0.8509	1.20	1.0	5823
41	41	42	0.3100	0.3623	0.0	0.0	5823
42	42	43	0.0410	0.0478	6.0	4.30	5823
43	43	44	0.0092	0.0016	0.0	0.0	5823
44	44	45	0.1089	0.1373	39.22	26.30	5823
45	45	46	0.0009	0.0012	39.22	26.30	6709
46	46	47	0.0034	0.0084	0	0.0	10761
47	47	48	0.0851	0.2083	79.00	56.40	10761
48	48	49	0.2898	0.7091	384.70	274.50	10761
49	49	50	0.0822	0.2011	384.70	274.50	10761
50	50	51	0.0928	0.0473	40.50	28.30	1899
51	51	52	0.3319	0.1114	3.60	2.70	2200
52	52	53	0.1740	0.0886	4.35	3.50	1899
53	53	54	0.2030	0.1034	26.40	19.00	1899
54	54	55	0.2842	0.1447	24.00	17.20	1899
55	55	56	0.2813	0.1433	0.0	0.0	1899

56	56	57	1.5900	0.5337	0.0	0.0	2200
57	57	58	0.7837	0.2630	0.0	0.0	2200
58	58	59	0.3042	0.1006	100.00	72.00	1455
59	59	60	0.3861	0.1172	0.0	0.00	1455
60	60	61	0.5075	0.2585	1244.0	888.00	1899
61	61	62	0.0974	0.0496	32.00	23.00	1899
62	62	63	0.1450	0.0738	0.0	0.0	1899
63	63	64	0.7105	0.3619	227.00	162.00	1899
64	64	65	1.0410	0.5302	59.00	42.00	1899
65	65	66	0.2012	0.0611	18.00	13.00	1455
66	66	67	0.0047	0.0014	18.00	13.00	1455
67	67	68	0.7394	0.2444	28.00	20.00	1455
68	68	69	0.0047	0.0016	28.00	20.00	1455
69	11	43	0.5000	0.5000			566
70*	13	21	0.5	0.5			566
71*	15	46	1.0	1.0			400
72*	50	59	2.0	2.0			283
73*	27	65	1.0	1.0			400

Table 3: Line Data for 69 Bus System

Comparison of load flow results for 69-node RDN

Node Number	Voltage Magnitude (p.u.)	Voltage Magnitude (BR) (p.u.)	Node Number	Voltage Magnitude (p.u.)	Voltage Magnitude(BR) (p.u.)
1	1.00000	1.00000	36	0.99972	0.99972
2	0.99997	0.99997	37	0.99975	0.99975
3	0.99993	0.99993	38	0.99959	0.99959
4	0.99984	0.99984	39	0.99954	0.99954
5	0.99902	0.99902	40	0.99954	0.99954
6	0.99008	0.99008	41	0.99884	0.99884
7	0.98079	0.98079	42	0.99855	0.99855
8	0.97857	0.97857	43	0.99854	0.99854
9	0.97744	0.97744	44	0.99850	0.99850
10	0.97243	0.97244	45	0.99841	0.99841
11	0.97131	0.97132	46	0.99840	0.99840
12	0.96814	0.96814	47	0.99979	0.99979
13	0.96521	0.96523	48	0.99469	0.99469
14	0.96231	0.96233	49	0.99415	0.99415
15	0.95943	0.95946	50	0.97854	0.97854
16	0.95890	0.95893	51	0.97853	0.97853
17	0.95802	0.95805	52	0.97465	0.97465
18	0.95801	0.95804	53	0.97141	0.97141
19	0.95754	0.95758	54	0.96693	0.96695
20	0.95724	0.95725	55	0.96256	096260
21	0.95676	0.95678	56	0.94004	0.94006
22	0.95675	0.95679	57	0.92894	0.92894
23	0.95668	0.95668	58	0.92464	0.92464
24	0.95652	0.95659	59	0.91958	0.91958
25	0.95635	0.95639	60	0.91217	0.91218
26	0.95628	0.95628	61	0.91188	0.91188

27	0.95626	0.95626	62	0.91149	0.91167
28	0.99993	0.99993	63	0.90958	0.90959
29	0.99985	0.99985	64	0.90901	0.90902
30	0.99973	0.99973	65	0.97125	0.97126
31	0.99971	0.99971	66	0.97125	0.97126
32	0.99961	0.99961	67	0.96781	0.96782
33	0.99935	0.99935	68	0.96781	0.96782
34	0.99901	0.99901	69	0.09575	0.95756
35	0.99898	0.99898			

Table 4: Comparison of load flow results for 69-node RDN

IV. CONCLUSIONS AND SCOPE FOR FUTURE WORK

The work has been carried out to find the optimal locations and sizes (kVAr) of capacitors to be placed in radial distribution system. the candidate locations for compensation are found using loss sensitivity factor calculated from base case load flow.The allocation problem, which is identification of location and size by one dimensional array. The study has been carried out on 33-bus and 69 bus considering the capacitors step sizes of 10 to 40 kVAr and 12 to 42

REFERENCES

[1] Salama M. M. A., and Chikhani A. Y., "A simplified network approach to the VAR control problem for radial distribution systems", IEEE Transaction on Power Delivery, 8 (3), pp. 1529-1535, 1993.
[2] Da Costa V. M., Martins N., and Pereira J. L. R., "Developments in the Newton- Raphson power flow formulation based on current injections", IEEE Trans. on Power Systems, 14 (4), pp. 1320-1326, 1999.
[3] Venkatesh B. Rangan R., and Gooi H. B. ,"Optimal reconfiguration of radial distribution systems to maximize loadability", IEEE Transactions on Power Systems, Vol. 19, No. 1, pp. 260-266, 2004.
[4] Shirmohammadi D., Hong H. M., Semlyen A., and Luo G. X., "A Compensation based Power Flow for weakly Meshed Distribution and Transmission Networks", IEEE Trans. On Power Systems, Vol. 3, pp.753-762,1988.
[5] W.Tinney and C.Hart, "Power Flow Solution by Newton's Method", IEEE Transactions on Power Apparatus and Systems, Vol.PAS-86, no.11, pp.1449-1460, November. '1967.
[6] B.Stott and O.Alsac, "Fast Decoupled Load-flow", IEEE Transactions on Power Apparatus and Systems, Vol.PAS-93, no.3, pp.859-869, May 1974.
[7] F. Zhang and C. S. Cheng, "A Modified Newton Method for Radial Distribution System Power Flow Analysis", IEEE Transactions on Power Systems, Vol.12, no.1,pp.389-397, February 1997.
[8] G.B. Jasmon, L.H.C. Lee, Distribution Network Reduction for Voltage Stability Analysis and Load Flow Calculations, Electrical Power & Energy Systems, Vol.13, no:1, pp. 9-13, 1991.
[9] T. H. Chen, M. S. Chen, K. J. Hwang, P. Kotas, and E. A. Chebli, "Distribution System Power Flow Analysis-A Rigid Approach", IEEE Transactions on Power Delivery, Vol.6, no.3, pp.1146-1153, July1991.
[10] Whei-Min Lin, Jen-HaoTeng, "Three-Phase Distribution Network Fast-Decoupled Power Flow Solutions", Electrical Power and Energy SystemsVol.22, pp.375-380, 2000.
[11] J. H. Teng, "A Modified Gauss-Seidel Algorithm of Three-phase Power Flow Analysis In Distribution Networks", Electrical Power and Energy Systems Vol.24,2002

