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Congestion Alleviation using Reactive Power Compensation in Radial Distribution Systems

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Abstract: *Congestion management is one of the most important things for safe and reliable operations in a radial distribution system. To improve the overall efficiency of a power system, the performance of distribution system must be improved and this is done by congestion management. In this paper a method is proposed for distribution line over load alleviation in a radial distribution system by allocating shunt capacitor at the receiving end node of an overloaded line .The over loaded line of a radial distribution system can be determined by considering reactive loading index range. It is shown that the line at which the value of reactive loading index is minimum is considered to be the over loaded line of the system and the size of the shunt capacitor value is determined as where the reactive power flow of the loaded line is compensated maximally by taking random capacitor values. Without violating the generator limits, the congestion in the line is alleviated to the considerable limits.*
The proposed method has been successfully tested on IEEE 12 bus and 10 bus radial distribution systems using ETAP 14 software.
Keywords: *Radial distribution system, Reactive Loading Index, weakest branch congestion alleviation, capacitor placement.*

I. Introduction

The main function of an electrical power distribution system is to provide power to individual consumer premises. Distribution of electric power to different consumers is done with much low voltage level.in radial distribution systems when the distributor is connected to substation on one end only with the help of feeder, then the system is called radial distribution system. The feeders, distributors and service mains are radiating away from the substation hence name given as radial system. Due to such system, if the fault occurs either on feeder or a distributor, all the consumers connected to that distributor will get affected. There would be an interruption of supply to all such consumers. The electric power that can be transmitted between two locations on a distribution network is limited by several transfer limits such as thermal limits, voltage limits and stability limits. When such a limit is reached, the system is said to be congested [1],[2],[3],[4].The power system operates within its limits is important to maintain power system security, reliability, failing which can result outages in the feeder lines and blackouts in the system. Congestion alleviation is important to maintain the system sTable. and reliable. There are several papers which propose different methods for congestion alleviation in which reactive power compensation is one of the method.

II. Reactive Power Compensation

Since most loads are inductive and consume lagging reactive power, the compensation required is usually supplied by leading reactive power. Shunt compensation of reactive power can be employed either at load level, substation level, or at transmission level. It can be capacitive (leading) or inductive (lagging) reactive power, although in most cases compensation is capacitive. The most common form of leading reactive power compensation is by connecting shunt capacitors to the line. Theoretically it is always desired to commission a capacitor nearer to reactive load. This makes transmission of reactive KVARS is removed from a greater part of the network. Moreover if capacitor and load are connected simultaneously, during disconnection of load, capacitor is also disconnected from rest of the circuit. Hence, there is no question of over compensation. But connecting capacitor with each individual load is not practical in the economical point of view. A shunt capacitor at the end of a feeder results in a gradual change in voltage [7]along the feeder. Ideally, the percent voltage rise at the capacitor would be zero at no load and rise to maximum at full load. However, with shunt capacitors, percent voltage rise is essentially independent of load. Utilities use shunt capacitors at distribution and utilization voltages to provide reactive power near the inductive loads that require it[5],[6],[8]. This reduces the total current flowing on the distribution feeder, which improves the voltage profile along the feeder, frees additional feeder capacity, and reduces losses. By compensating reactive power in the overloaded line in radial distribution network using shunt capacitor the following benefits are going to happen.

1. Improvement in voltage profile.
2. Increase in power transfer capability.
3. Decrease in branch losses.
4. Decrease in line currents.

The above things are proved in this paper and have been successfully tested in IEEE 12 and 10 bus radial distribution systems.

III. Step By Step Procedure

Step 1: Run power flow for12 bus radial distribution system.
Step 2: From the load flow results, find the reactive loading index and its maximum range values for each branch.
Step 3: Find the difference between the maximum range value (sinα) and reactive loading index of each branch. The branch which is having high difference value will be considered as weakest branch or heavily loaded branch. The receiving end of the weakest branch is considered as the optimal location for capacitor placement.
Step 4: Consider the first 4 weakest branches in the network.
Step 5: Incorporate a shunt capacitor at the receiving end of the each weakest branch with random ratings.
Step 6: The capacitor value will be optimal where the reactive power compensation is maximum by satisfying voltage and generating limits.
Step 7: Tabulate the corresponding values of all bus voltages, losses and KVA flow of each line in the network by placing optimal capacitor.
Step 8: Compare the results from step 2 and step 7.
Step 9: Before placement of capacitor and after placement of capacitor results for voltage, line flows and losses are compared and shown in figures 3&4.

IV. Reactive Loading Index

A distribution system consists of 2 numbers of nodes. Normally, a number of branches are series connected to form a radial feeder in low voltage distribution system which is shown in Figure 1. Consider branch i in Figure 1 which is connected between buses 1 and 2(where 1 is closer to the source or generator bus).

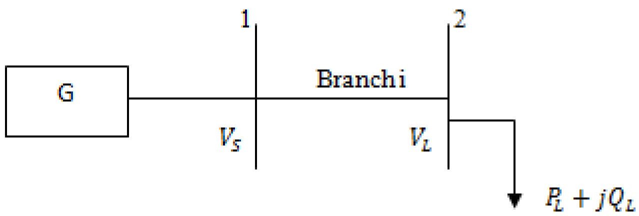

Figure1. A radial feeder of a distribution system

Let branch line b_{12} where 1 and 2 are respectively two nodes of the branch and node 1 is source node (source voltage, $V_S = V_S \angle \delta_S$) and node 2 is load or receiving end node (load voltage, $V_L = V_L \angle \delta_L$).Therefore power flow direction is from node 1 to node 2.The load flow from node 2 is $P_L + jQ_L$. Here a load having an impedance of $Z_L = Z_L \angle ø$ is connected to a source through an impedance of $Z_S = Z_S \angle \alpha$. If line shunt admittances are neglected, the current flowing through the line equals the load current;
Therefore, we can write

$$\frac{V_S - V_L}{Z_S} = \frac{S_L^*}{V_L^*} = \frac{P_L - jQ_L}{V_L^*} \qquad (1)$$

Or, $$\frac{V_S \angle \delta_S - V_L \angle \delta_L}{Z_S \angle \alpha} = \frac{P_L - jQ_L}{V_L \angle -\delta_L}$$

Using this simple calculation, we can write load reactive power Q_L as

$$Q_L = \frac{V_S V_L}{Z_S}\sin(\delta_L + \alpha - \delta_S) - \frac{V_L^2}{Z_S}\sin\alpha \qquad (2)$$

The load voltage V_L can be varied by changing the load reactive power Q_L. The load reactive power Q_L becomes maximum when the following condition becomes satisfied.

$$\frac{dQ_L}{dV_L} = 0 \qquad (3)$$

Now from equations (2) and (3)

$$\frac{dQ_L}{dV_L} = \frac{V_S}{Z_S}\sin(\delta_L + \alpha - \delta_S) - \frac{2V_L}{Z_S}\sin\alpha = 0$$

Hence, $\sin(\delta_L + \alpha - \delta_S) = 2\mathrm{V_L}\sin\alpha$ (4)

Putting the value of $\mathrm{V_S}\sin(\delta_L + \alpha - \delta_S)$ in equation (2) , we get maximum value of load reactive power .Hence,

$$Q_L^{max} = \frac{V_L^2}{Z_S}\sin\alpha \qquad (5)$$

From equation (4),we can write

$$2\frac{\mathrm{V_L}}{\mathrm{V_S}}\sin\alpha - \sin(\delta_L + \alpha - \delta_S) = 0 \qquad (6)$$

Now at no load, $V_L = V_S$ and $\delta_L = \delta_S$. Thus at no load the left hand side (LHS) of equation (6) will be $\sin\alpha$. However, at the maximum reactive power Q_L,the equality sign of equation (6) hold thus the LHS of equation (6) becomes zero.
Hence the LHS of equation (6) may be considered as reactive loading index (L_q) of the system that varies between sinα at no load and zero at maximum reactive power. Thus

$L_q = 2\frac{V_L}{V_S}\sin\alpha - \sin(\delta_L + \alpha - \delta_S)$ (7)

By considering $\delta_L = \delta_S$, we can write from equation (7),

$L_q = \left(\frac{2V_L}{V_S} - 1\right)\sin\alpha$ (8)

Here, $\sin\alpha \geq L_q \geq 0$ (9)

Now the impedance Z_S of a branch or line is connected between the source and the load buses for a two bus system. In this paper L_q is defined as the reactive loading index of the branch.

From Figure 1, the reactive loading index $(L_q)_i$ of branch i can be written as

$(L_q)_i = 2\frac{V_L}{V_S}\sin\alpha - \sin\alpha$ (10)

Similarly, the reactive loading index of all branches of feeder can be determined from equation (10).

V. Simulations and Discussion

Case (i): IEEE 12 Bus Radial Distribution System.

Consider a IEEE 12 bus radial distribution network having one generator of11KV,100 MVA, 90% efficiency,0.85 P.F,with 12 nodes and 11 branches and 11 loads are connected as shown in figure 2.The line and load data of IEEE 12 bus distribution system is tabulated in Table.1.

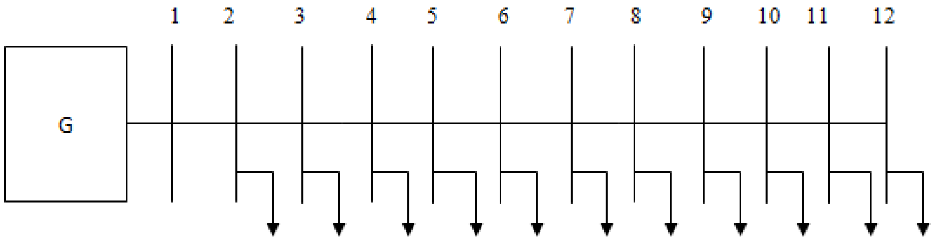

Fig-2: IEEE 12 bus radial feeder of distribution system

Table.1 Line and Load Data

From	To	R(ohm)	X(ohm)	load node	KW	KVAR
1	2	1.093	0.455	2	60	60
2	3	1.184	0.494	3	40	30
3	4	2.095	0.873	4	55	55
4	5	3.188	1.329	5	30	30
5	6	1.093	0.455	6	20	15
6	7	1.002	0.417	7	55	55
7	8	4.403	1.215	8	45	45
8	9	5.642	1.597	9	40	40
9	10	2.89	0.818	10	35	30
10	11	1.154	0.428	11	40	30
11	12	1.238	0.351	12	15	15

The load flows of IEEE 12 bus radial distribution system is tabulated in Table.2, in which node voltages are used to determine the reactive loading index of each line in the system .

Table.2: Simulation Results

FROM	TO	POWER FLOWS		KVA	AMP	V(P.U)	LINE LOSS	
		KW	KVAR				KW	KVAR
1	2	426.2	387.6	576.1	30.2	0.9947	3	1.25
2	3	363.9	326.9	489.2	25.8	0.9898	2.37	0.987
3	4	322.3	296.6	438	23.2	0.982	3.39	1.41
4	5	265.9	242.1	359.6	19.2	0.9721	3.53	1.47
5	6	234	212.3	315.9	17.1	0.9691	0.954	0.397
6	7	214.3	197.8	291.6	15.8	0.9666	0.75	0.312
7	8	162.1	146.1	218.2	11.9	0.9591	1.85	0.474
8	9	118.9	104.2	158.1	8.7	0.9519	1.27	0.359
9	10	81.4	67.6	105.8	5.8	0.9494	0.295	0.084
10	11	49.5	40.5	64	3.5	0.9487	0.043	0.016
11	12	13.5	13.5	19.1	1.1	0.9485	0.004	0.001

From the above Table.2 it is clearly observed that all the line flows and voltages are within the limits. From these results $(L_q)_{max}$ and L_q are calculated as follows.

Table.3 Reactive Loading Index And Its Maximum Range For Different Branches

Branch No.	$(L_q)_{max} = \sin\alpha$ $(\alpha = \tan^{-1}\frac{X}{R})$	$L_q=\left(\frac{2V_L}{V_S} - 1\right)\sin\alpha$	Difference	Rank
1	0.384315	0.380241	0.004074	5
2	0.385058	0.381264	0.003794	6
3	**0.384646**	**0.378583**	**0.006063**	**2**

4	**0.384779**	**0.37702**	**0.007759**	**1**
5	0.232541	0.381943	0.002372	7
6	0.384222	0.382239	0.001983	8
7	**0.266006**	**0.261878**	**0.004128**	**3**
8	**0.272355**	**0.268265**	**0.004090**	**4**
9	0.272345	0.270914	0.001431	9
10	0.272034	0.271633	0.000401	10
11	0.27277	0.272655	0.000115	11

From the above Table.3, it is observed that branches 4,3,7,8 are congested and ranked 1,2,3,4 respectively. Here first four congested lines are considered and the congested branches in rank wise are listed below,

a) branch 4(4-5) get rank 1
b) branch 3(3-4) get rank 2
c) branch 7 (7-8) get rank 3
d) branch 8(8-9) get rank 4

From the above information the receiving end of each congested line node is considered as optimal location or shunt capacitor and the locations are 5,4,8,9 and connecting a shunt capacitor with random ratings is placed at these nodes individually .Which compensates maximum reactive power in the congested line without violating the generating limits will be the optimal capacitor size.

a) Optimal Capacitor For Branch 4 At Node 5

The following are the results after at node 4 with different ratings and the corresponding power flows are compared with the power flows with capacitor.

Table.4 Different Ratings of Capacitor Placed At Node 5

Node		Power Flow Without C		C=0.25MVAR		C=0.253MVAR		C=.255MVAR		C=0.256MVAR	
from	to	P(KW)	Q(KVAR)	P(KW)	Q(KVAR)	P(KW)	Q(KVAR)	P(KW)	Q(KVAR)	P(KW)	Q(KVAR)
1	2	426.2	387.6	425	149.8	425	146.9	425.1	145	425.1	144.1
2	3	363.9	326.9	363.7	89.5	363.7	86.7	363.8	84.8	363.8	83.8
3	4	322.3	296.6	323	59.5	323	56.6	323.1	54.7	323	53.7
4	5	265.9	242.1	267.6	5.24	267.7	2.35	267.7	0.464	267.7	-0.522
5	6	234	212.3	237	215	237	215	237.1	215.1	237.1	215.1
6	7	214.3	197.8	217	200.3	217	200.4	217.1	200.4	217.1	200.4
7	8	162.1	146.1	164.2	148	164.2	148	164.3	148	164.2	148
8	9	118.9	104.2	120.4	105.5	120.4	105.6	120.5	105.6	120.4	105.6
9	10	81.4	67.6	82.4	68.5	82.4	68.5	82.5	68.5	82.4	68.5
10	11	49.5	40.5	50.2	41	50.2	41	50.2	41	50.2	41
11	12	13.5	13.5	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7

From above Table.4 it is clear that at node 5 C=0.255 MVAR compensating maximum reactive power flow. So this is the optimal size of the capacitor.

Table.5 When Capacitor C=0.255 MVAR at Node 5

FROM	TO	POWER FLOWS		KVA	AMP	V(P.U)	LINE LOSS	
		KW	KVAR				KW	KVAR
1	2	425.1	145	449.1	23.6	0.9956	1.82	0.757
2	3	363.8	84.8	373.5	19.7	0.9917	1.38	0.574
3	4	323.1	54.7	327.6	17.3	0.9857	1.89	0.787
4	5	267.7	0.464	267.7	14.3	0.9785	1.94	0.81
5	6	237.1	215.1	320.1	17.2	0.9755	0.967	0.402
6	7	217.1	200.4	295.4	15.9	0.9729	0.759	0.316
7	8	164.3	148	221.1	11.9	0.9654	1.88	0.518
8	9	120.5	105.6	160.2	8.7	0.9581	1.28	0.363
9	10	82.5	68.5	107.2	5.9	0.9556	0.299	0.085
10	11	50.2	41	64.8	3.6	0.9549	0.058	0.016
11	12	13.7	13.7	19.3	1.1	0.9547	0.004	0.001

The line flows, node voltages and line losses and line looses of IEEE 12 bus radial distribution system when capacitor C=0.255 MVAR is placed at node 5 is tabulated in Table.5.

b) Optimal Capacitor For Branch 3 At Node 4

Table.6 Different Ratings of Capacitor at Node 4

Node		Power Flow Without C		C=0.31MVAR		C=0.305MVAR		C=0.306MVAR		C=0.307MVAR	
From	To	P(KW)	Q(KVAR)	P(KW)	Q(KVAR)	P(KW)	Q(KVAR)	P(KW)	Q(KVAR)	P(KW)	Q(KVAR)
1	2	426.2	387.6	425.5	87.3	425.6	92.1	425.6	91.2	425.6	89.2
2	3	363.9	326.9	364.4	27	364.3	31.9	364.3	30.9	364.3	29
3	4	322.2	296.6	323.7	-3.06	323.6	1.81	323.6	0.837	323.7	-1.11
4	5	265.9	242.1	268.3	244.3	268.3	244..3	268.3	244.3	268.3	244.3
5	6	234	212.3	236.1	214.2	236.1	214.2	236.1	214.2	236.1	214.2
6	7	214.3	197.8	216.2	199.6	216.2	199.6	216.2	199.6	216.2	199.6
7	8	162.1	146.1	163.6	147.4	163.6	147.4	163.6	147.6	163.6	147.4
8	9	118.9	104.2	120	105.2	120	105.1	120	105.1	120	105.2
9	10	81.4	67.6	82.1	68.2	82.1	68.2	82.1	68.2	82.1	68.2
10	11	49.5	40.5	50	40.9	50	40.8	50	40.8	50	40.8
11	12	13.5	13.5	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6

From above Table. 6 it is clear that at node 4 C=0.306 MVAR compensating maximum reactive power flow. So this is the optimal size of the capacitor.

Table.7 When Capacitor C=0.306 at Node 4

FROM	TO	POWER FLOWS		KVA	AMP	V(P.U)	LINE LOSS	
		KW	KVAR				KW	KVAR
1	2	425.6	91.2	435.2	22.8	0.9958	1.71	0.712
2	3	364.3	30.9	365.6	19.3	0.9921	1.32	0.55
3	4	323.6	0.837	323.6	17.1	0.9865	1.84	0.768
4	5	268.3	244.3	362.8	19.3	0.9766	3.56	1.49
5	6	236.1	214.2	318.8	17.1	0.9736	0.963	0.401
6	7	216.2	199.6	294.2	15.9	0.971	0.756	0.315
7	8	163.6	147.6	220.2	11.9	0.9634	1.87	0.516
8	9	120	105.1	159.5	8.7	0.9561	1.28	0.362
9	10	82.1	68.2	106.7	5.9	0.9536	0.298	0.084
10	11	50	40.8	64.5	3.6	0.9528	0.057	0.016
11	12	13.6	13.6	19.2	1.1	0.9526	0.004	0.001

The line flows, node voltages and line losses and line looses of IEEE 12 bus radial distribution system when capacitor C=0.306 MVAR is placed at node 4 is tabulated in Table.6.

c) Optimal Capacitor For Branch 7 At Node

Table.8 Different Ratings of Capacitor at Node 8

Node		Power Flow Without C		C=0.16MVAR		C=0.159MVAR		C=0.158MVAR		C=0.157MVAR	
From	To	P(KW)	Q(KVAR)	P(KW)	Q(KVAR)	P(KW)	Q(KVAR)	P(KW)	Q(KVAR)	P(KW)	Q(KVAR)
1	2	426.2	387.6	424.1	239.4	424.1	240.4	424.1	241.3	424.1	242.2
2	3	363.9	326.9	362.5	179.1	362.5	180	362.5	180.9	362.5	1
3	4	322.3	296.6	321.6	148.9	321.6	149.9	321.6	150.8	321.6	181.9
4	5	265.9	242.1	266.1	94.7	266.1	95.7	266.1	96.6	266.1	151.7
5	6	234	212.3	235.3	65.3	235.3	66.2	235.3	67.1	235.3	68
6	7	214.3	197.8	215.8	50.8	215.8	51.7	215.8	52.7	215.8	52.9
7	8	162.1	146.1	163.5	-1.31	163.4	-0.375	163.4	0.557	163.4	1.457
8	9	118.9	104.2	120.5	105.6	120.5	105.6	120.5	105.6	120.5	105.6
9	10	81.4	67.6	82.5	68.5	82.5	68.5	82.5	68.5	82.5	68.5
10	11	49.5	40.5	50.2	41	50.2	41	50.2	41	50.2	41
11	12	13.5	13.5	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7

From above Table. 8 it is clear that at node 8 C=0.158 MVAR compensating maximum reactive power flow. So that it is the optimal size of the capacitor.

Table.9 When Capacitor C=0.158 MVAR at Node 8

FROM	TO	POWER FLOWS		KVA	AMP	V(P.U)	LINE LOSS	
		KW	KVAR				KW	KVAR
1	2	424.1	241.3	487.9	25.6	0.9953	2.15	0.895
2	3	362.5	180.9	405.1	21.4	0.991	1.62	0.676
3	4	321.6	150.8	355.2	18.8	0.9842	2.22	0.927
4	5	266.1	96.6	283	15.1	0.976	2.18	0.908
5	6	235.3	67.1	244.7	13.2	0.9736	0.568	0.236
6	7	215.8	52.7	222.1	12	0.9716	0.431	0.179
7	8	163.4	0.557	163.4	8.8	0.9655	1.03	0.284
8	9	120.5	105.6	160.2	8.7	0.9582	1.28	0.363
9	10	82.5	68.5	107.2	5.9	0.9557	0.299	0.085
10	11	50.2	41	64.8	3.6	0.9549	0.058	0.016
11	12	13.7	13.7	19.3	1.1	0.9547	0.004	0.001

The line flows, node voltages and line losses and line looses of IEEE 12 bus radial distribution system when capacitor C=0.158 MVAR is placed at node 8 is tabulated in Table.9.

d) Optimal Capacitor For Branch 8 At Node 9

Table.9 Different Ratings of Capacitor at Node 9

Node		Power Flows Without C		C=0.12MVAR		c=0.11MVAR		c=0.115MVAR		C=0.114MVAR	
From	To	P(KW)	Q(KVAR)	P(KW)	Q(KVAR)	P(KW)	Q(KVAR)	P(KW)	Q(KVAR)	P(KW)	Q(KVAR)
1	2	426.2	387.6	424	278.2	424	287.3	424	282.8	424	283.7
2	3	363.9	326.9	362.2	217.7	362.2	226.9	362.2	22.3	362.2	233.2
3	4	322.3	296.6	321.2	187.6	321.1	196.7	321.1	192.1	321.1	193.1
4	5	265.9	242.1	265.5	133.3	265.4	142.5	265.4	137.9	265.4	138.1
5	6	234	212.3	234.6	103.6	234.4	112.9	234.5	108.4	234.5	109.3
6	7	214.3	197.8	215	89.4	214.9	98.5	215	93.9	214.9	94.8
7	8	162.1	146.1	162.8	37.4	162.6	46.5	162.7	41.9	162.7	42.9
8	9	118.9	104.2	119.9	-4.71	119.8	4.47	119.8	-0.117	119.8	0.8
9	10	81.4	67.6	82.4	68.5	82.4	68.4	82.4	68.5	82.4	68.4
10	11	49.5	40.5	50.2	41	50.1	41	50.2	41	50.2	41
11	12	13.5	13.5	13.7	13.7	13.6	3.6	13.7	13.7	13.7	13.7

From Table.9 it is clear that at node 9 C=0.114 MVAR compensating maximum reactive power flow. So that it is the optimal size of the capacitor.

Table.10 When Capacitor C=0.114 MVAR at Node 9

FROM	TO	POWER FLOWS		KVA	AMP	V(P.U)	LINE LOSS	
		KW	KVAR				KW	KVAR
1	2	424	283.7	510.1	26.8	0.995	2.35	0.979
2	3	362.2	233.2	425.4	22.4	0.9906	1.79	0.746
3	4	321.1	193.1	374.7	19.9	0.9836	2.48	1.03
4	5	265.4	138.1	299.5	16	0.9749	2.44	1.02
5	6	234.5	109.3	258.7	13.9	0.9724	0.636	0.265
6	7	214.9	94.8	234.9	12.7	0.9702	0.483	0.201
7	8	162.7	42.9	168.2	9.1	0.9636	1.09	0.302
8	9	119.8	0.8	119.8	6.5	0.9578	0.721	0.204
9	10	82.4	68.4	107.1	5.9	0.9553	0.299	0.085
10	11	50.2	41	64.8	3.6	0.9545	0.058	0.016
11	12	13.7	13.7	19.3	1.1	0.9543	0.004	0.001

The line flows, node voltages and line losses and line looses of IEEE 12 bus radial distribution system when capacitor C=0.114 MVAR is placed at node 9 is tabulated in Table.10.

VI. Results

From the above analysis it can be observed that the compensation of reactive power compensation in the overloaded branch will leads to increase in voltage profile, decrease in branch currents in congested line leads to decrease in KVA and decrease in branch losses. The changes after capacitor placement at the receiving end of loaded branch are shown in Table. 11

Figure.2 Improvement in Voltage Profile after Capacitor Placement

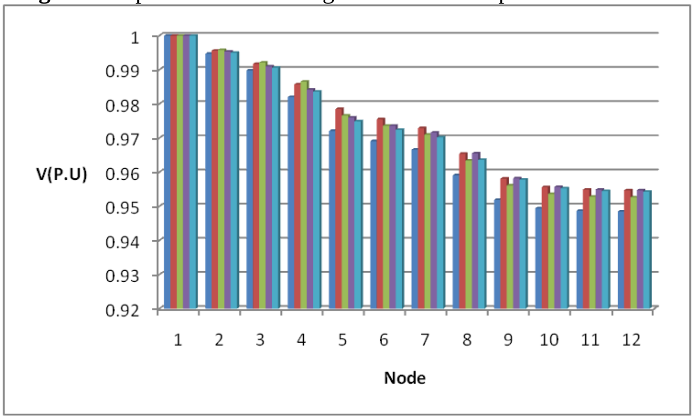

Figure.3 Decrease in KVA Flow in the Branches after Capacitor Placement

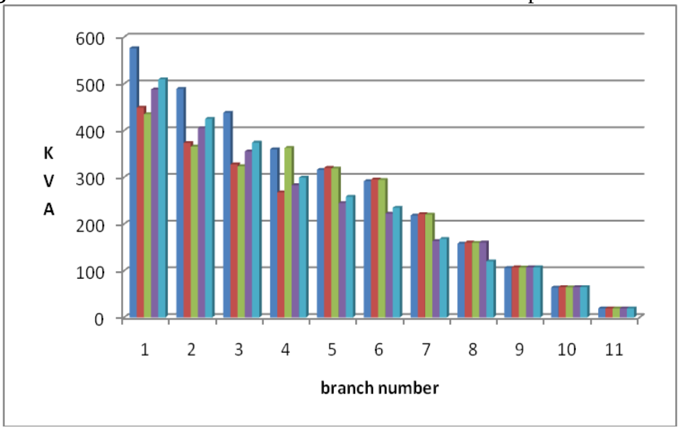

Table.11 Changes in Values before and After Compensation

	Without capacitor	C=0.255 MVAR At node 5	C=0.306 MVAR At node 4	C=0.158 MVAR At node 8	C=0.114 MVAR At node 9
Vmin(p.u)	0.9485	0.9547	0.9526	0.9547	0.9543
Vmax(p.u)	0.9947	0.9956	0.9958	0.9953	0.9951
Total active power loss	17.5KW	12.3 KW	13.7 KW	11.8 KW	12.4 KW
Total reactive power loss	6.8KVAR	4.6 KVAR	5.2 KVAR	4.6 KVAR	4.8 KVAR

Case (ii): 10 bus radial distribution system.

The same analysis is done on the 10 bus radial distribution system and the results are shown below

Figure.4 Improvement in Voltage Profile after Capacitor Placement

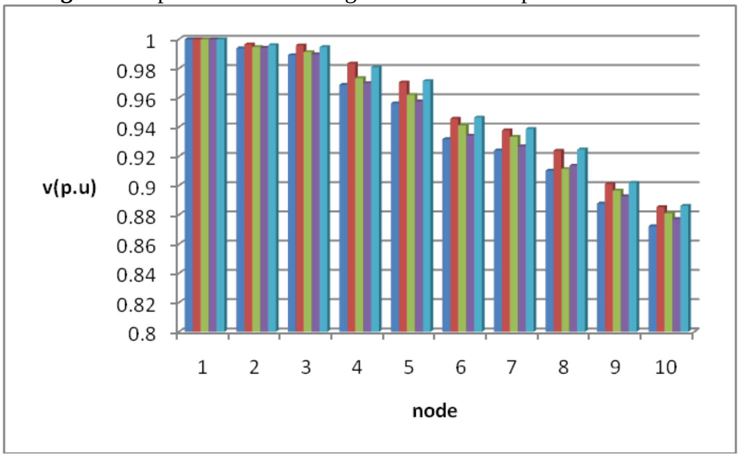

Figure.5 Decrease in KVA Flow In The Branches After Capacitor Placement

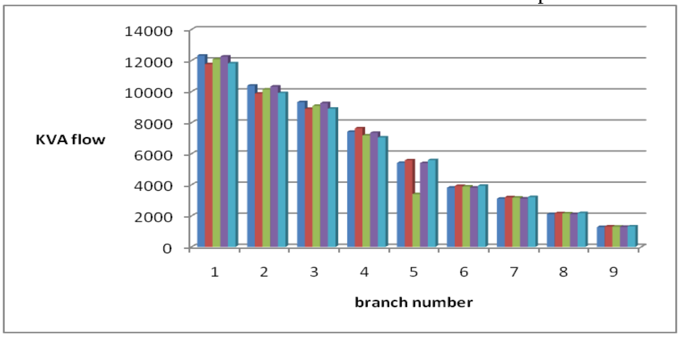

Table.11 Changes in Values before and After Compensation

	Without capacitor	C=3.684 MVAR At node	C=1.279 MVAR At node 4	C=0.373 MVAR At node 8	C=3.122 MVAR At node 9
Vmin(p.u)	0.8722	0.8853	0.88	0.8771	0.8861
Vmax(p.u)	0.9938	0.9965	0.9947	0.9941	0.996
Total active power loss	503.4KW	497.3 KW	490.3 KW	498.5 KW	487.2 KW
Total reactive power loss	706.9 KVAR	670.9 KVAR	680.3 KVAR	698.8 KVAR	664.2 KVAR

VII. Conclusion

From the above analysis and from Table.10 and Table.11 it is cleared that the placement of optimal capacitor at the receiving end of the congested line by compensating the reactive power will leads to increase in voltage profile, decrease in currents in loaded lines, decrease in KVA flows and decrease in overall line losses. And will helps in the analysis of practical power system networks.

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