Optimal Placement of Capacitor by Using PSO With Considering Harmonics in Distribution Systems

T.S.R.Prasanti[1], I.Murali Krishna[2], B.Lovaraju[3]
1. PG Scholar, Department of Electrical and Electronics Engineering, Pragati Engineering College, Surampalem,Andhra Pradesh
2. Assistant Professor, Department of Electrical and Electronics Engineering, Pragati Engineering College, Surampalem, Andhra Pradesh
3. Assistant Professor, Department of Electrical and Electronics Engineering, Pragati Engineering College, Surampalem, Andhra Pradesh

Abstract— This paper presents a new approach in order to determine the optimal placement of capacitor in radial distribution system. The power loss is significantly high in distribution systems because of lower voltages and higher currents. Optimal capacitor placement results in system loss reduction, power factor correction, voltage profile improvement and additional feeder capacity can be released. The capacitor placement is done by considering parameters like Loss sensitivity factor and better Voltage profile. Particle Swarm Optimization (PSO) algorithm is used for determination of the location system capacitor placement. In the proposed algorithm depending upon loss sensitivity factor, number of iteration required for deriving better volage profile is possible to reduce.For, 25-bus three phase unbalanced and balanced system is considered for capacitive compensation. Three phase load flow solution is obtained by using topology based load flow program in MATLAB environment and time required, accuracy has been found satisfying.

Index Terms— particle swarm optimization algorithm (PSO), Radial Distribution Power Flow (RDPF), Optimal Capacitors Placement, unbalanced radial distribution system (URDS),Optimization, Loss sensitivity factor, Harmonics.

1 Introduction

It is well known fact that major portion of power system losses occur at the distribution level only. In distribution systems the reactive requirement will increase the losses in active power flow and poor voltage profile and decreases system stability. Some of these losses can be eliminated by proper selection of shunt capacitors on primary feeders via power factor correction. Capacitors have been most commonly used, to provide reactive power compensation in distribution systems. These are provided to minimize power and energy losses, maintain good voltage profile for load buses and improve system security. The amount of compensation provided is very much linked to the placement of capacitors in the distribution system which is essential in determining the location, size, number and type of capacitors to be placed in the system [2]. A large variety of research work has been done on capacitor placement problem in the past [4], [6]. All the approaches differ from each other by the way of their problem formulation and the problem solution method employed.

Some of the early works have not considered capacitor cost in the formulation. In some approaches the objective function considered is to control the voltage. In some techniques, only fixed capacitors are considered and load changes which are very important in capacitor placement have not been considered. Other techniques have considered load changes only in three different levels. In addition, with the application of loads, the voltage profile tends to drop along distribution feeders below acceptable operating limits. Along with power losses and voltage drops, the increasing growth in electricity demand requires upgrading the infrastructure of distribution systems [3]. Shunt capacitors can be of great help in enhancing the performance of distribution systems. Distribution systems are inherently unbalanced for several reasons. First, distribution systems supply single and three-phase loads through distribution transformers. Second, the phases of transmission lines are unequally loaded. Third, overhead lines in distribution systems are not transposed [3].

Due to the widespread use of harmonic producing equipment in distribution systems, harmonics are propagated throughout those systems. Harmonics are undesirable and cause equipment overheating due to the excessive losses and potential malfunctioning of electric equipment. Inclusion of shunt capacitors without considering the presence of harmonic sources in the system may lead to an increase in harmonic distortion levels due to resonance between capacitors and the various inductive elements in the system. Different types of problem solution methods have been employed to solve the capacitor placement problem, such as, heuristic algorithm, hybrid differential evolution algorithm, genetic algorithms for optimisation and dynamic programs [5]. Although these techniques have solved the problem, most of early works used analytical methods with some kind of heuristics [1]. The problem formulation was oversimplified with certain assumptions, which lacked generality. There is also the problem of local minimal in some of these methods. Further more, since the capacitor banks are non continuous variables, taking them as continuous compensation, by some authors, can cause very high inaccuracy with the obtained results. Partical Swarm Optimization Algorithms (PSO) has been applied in various power system problems [6]. PSO is a very well known and capable method for optimization problems. It is capable of determining near global solution with lesser computational burden. In this respect, it is very suitable to solve the capacitor placement problem. In the present work PSO is applied to determine the optimal capacitors location for distribution network. Load model of different levels and load flow study are also considered in the system simulation.

2 PROBLEM METHODOLOGY

2.1 Review Stage

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 and 3. Formulation of bcbv matrix.

For distribution systems, the models which are based on the equivalent current injection are more convenient to use. At each bus the complex power, is specified by

$$S_i = (P_i + jQ_i) \qquad i = 1,2,......n \qquad (i)$$

And the corresponding equivalent current injection at the k^th^ iteration of the solution is

$$I_i^k = I_i^r (V_i^k) + jI_i^i (V_i^k) = \left(\frac{P_i + jQ_i}{V_i^k}\right)^* \qquad (ii)$$

V_i^k is the node voltage at the kth iteration

I_i^k is the equivalent current injection at the kth iteration

I_i^r, I_i^i are the real and imaginary parts of the equivalent current injection at the kth iteration respectively.

The BIBC matrix is responsible for the relations between the bus current injections and branch currents. The BCBV matrix is responsible for the relations between the branch currents and bus voltages.

$$\begin{aligned}[\Delta V]_{(n-1)\times 1} &= [BCBV]_{(n-1)\times m} * [BIBC]_{m\times(n-1)} * [I]_{(n-1)\times 1} \\ &= [DLF]_{(n-1)\times(n-1)} * [I]_{(n-1)\times 1} \qquad (iii)\end{aligned}$$

The algorithm steps for load flow solution of distribution system is given below:

Step1: Read the distribution system line data and load data.

Step 2: Form the bibc matrix by using steps. The relationship can be expressed as [b] = [bibc] [i]

Step 3: Form the bcbv matrix by using steps.The relationship can be expressed as [Δv] = [bcbv] [b]

Step 4: From the DLF matrix by using the eq. (iii). The relationship will be [dlf] = [bcbv][bibc][Δv] = [dlf][i]

Step 5: Set iteration k = 0.

Step 6: Iteration k = k + 1.

Step 7: Update voltages by using equation as

$$I_i^k = I_i^r (V_i^k) + jI_i^i (V_i^k) = \left(\frac{P_i + jQ_i}{V_i^k}\right)^*$$

$$[\Delta V^{k+1}] = [DLF][I^k]$$

$$V^{k+1} = [V^o] + [\Delta V^{k+1}]$$

Step 8: If max $((|i_i^{k+1}| - |i_i^k|) >$ tolerance) goto step 6.

Step 9: Calculate line flows, and losses from final bus voltages.

Step 10: Print bus voltages, line flows and losses.

Step 11: Stop

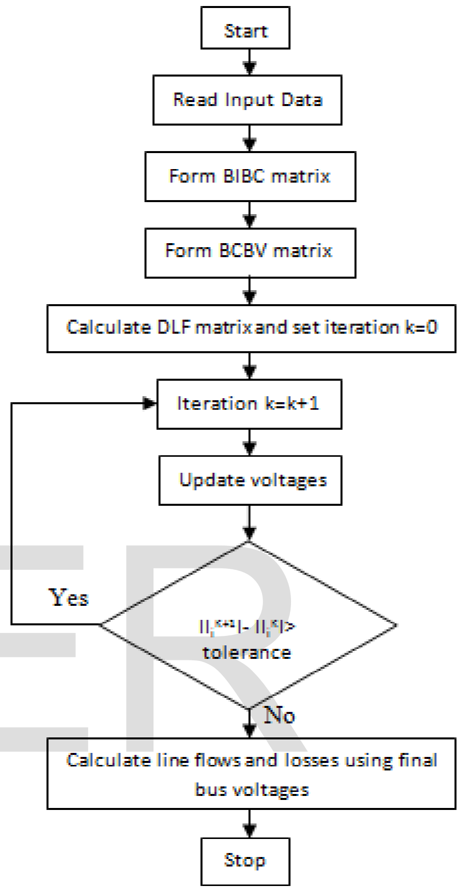

Fig1. Flowchart for load flow solution for radial distribution system

Sensitivity analysis:

Loss sensitivity factors are calculated for determining the candidate nodes for placement of capacitors. Estimation of these sensitive nodes helps in reducing the search space.

$$\frac{\partial P_{loss}}{\partial Q_2} = \frac{2 * Q_2 * R[j]}{V_2^2} \qquad (iv)$$

Loss sensitivity factors, are calculated using load flow and values are arranged in descending order for all the buses. The proposed ‘loss sensitive coefficient’ factors become very powerful and useful in capacitor allocation or placement. Normalized voltage magnitudes are calculated for all the buses.

$$Norm[i] = \frac{V[i]}{0.95} \qquad (v)$$

Buses, whose normalized values are less than 1.02, are considered as candidate nodes requiring compensation. Loss Sensi-

IJSER

tivity factors decide the sequence of in which buses are to be considered for capacitor placement and the normalized values of voltages decide, whether a particular bus needs compensation or not.

The objective function is to minimize the total power loss.

The objective function is given by

$F_{min} = Ploss$ (vi)

$Ploss = \sum_{i=1}^{nb} ploss_i$ (vii)

The fundamental component of the total real power loss is calculated using a three phase power flow algorithm. In this paper network topology based load flow is used to obtain voltages at each bus, branch currents. Note that the harmonic component of the total real power loss is small compared with the fundamental one. However, this portion of the total real power loss increases as harmonic-producing loads continue to increase in RDS. Consequently, the undesirable presence of harmonics will cause more equipment overheating, stress on equipment insulation and equipment failure. Not to mention of course the interference with communication networks. It should be pointed out that the cost of the real power loss per unit is fixed. However, the cost of the reactive power injection per unit varies from one capacitor to another. Generally, the larger the capacitor size is, the cheaper it becomes.

3. Solution Technique

Particle Swarm Optimization (PSO) is a meta heuristic parallel search technique. PSO is derived from simulation of a simplified social model of swarms (e.g. bird flocks or fish schools). The interaction of particles in swarm, using common evolutionary computation algorithm, guides the direction of swarm towards the optimal regions of search space. The main merits of PSO are computationally efficient, simplicity in concept and implementation, less computation time, and inexpensive memory for computer resource. In, PSO is employed to determine the optimal solution of capacitor placement problem with two objective functions. The first one is power loss minimization and the second objective function is cost minimization in a specified period of time. The former is employed as a global optimizer to optimally locate and rate shunt capacitors, while the latter is utilized to minimize the bus current mismatch equations (i.e., the power flow equations). The developed PSO algorithm starts with generating a swarm particles randomly in the feasible region of the search space. The feasible swarm is passed to the RDPF subroutine as initial guess to minimize bus current injection mismatch equations. Each particle recalls its best position records the best position achieved by the entire swarm.

using the following information:

- The current positions (x, y),
- The current velocities (,),
- The distance between the current position and
- The distance between the current position and .

Using the global best and individual best, the 1st particle velocity in kth dimension is updated according to the following equation.

V[i][j]=k*(w*v[i][j]+c1*rand1*(pbestX[i][j]-X[i][j]+c2*rand2*(gbestX[j]-X[i][j])) (viii)

Where , K -- constriction factor, 0.7259

C_1, C_2 -- weight factors 2, 2

w -- Inertia weight parameter 1.2

i -- particle number

j -- control variable

rand1, rand2 -- random numbers between 0 and 1

P^i_{best} is P^i_{best} of particle i, and

G_{best} is best of the group.

The following weighting function is usually utilized

$w= w_{max} – ((w_{max}-w_{min})/iter_{max}) x\ iter$ (ix)

Where w_{max} is initial weight, w_{min} is final weight, $iter_{max}$ is maximum iteration number, and iter is current iteration number.

The RHS of equation (i) consists of three terms (vectors). The first term is the previous velocity of the agent. The second and third terms are utilized to change the velocity of the agent. Without the second and third terms, the agent will keep on "flying" in the same direction until it hits the boundary. Namely, it tries to explore new areas and, therefore, the first term corresponds with *diversification* in the search procedure. On the other hand, without the first term, the velocity of the "flying" agent is only determined by using its current position and its best positions in history. Namely, the agents will try to converge to the their P_{best}s and/or G_{best} and, therefore, the terms correspond with *intensification* in the search procedure.

The current position (searching point in the solution space) can be modified by the following equation:

$S_i^{t+1} = S_i^t + v_i^{t+1}$ (x)

Harmonics: To include the presence of harmonics, harmonics are considered at various buses and integrated with PSO. The proposed (PSO) based approach is tested on the (25-bus-rds) 25 bus test system.

In this project the non linear currents magnitudes are assumed that the loads are diode rectifiers only, however the non linear load currents can be different for other loads. These can be included by considering the fundamental component based on their formulae.

Assuming the load resistance of suitable value fundamental rms current is calculated from above equation and 5th, 7th and 11th harmonics are included remaining higher order harmonics are neglected.

After considering the harmonics total actual current calculated these harmonics are assumed to be included at bus numbers 19, 20, 21, 25, 26, 27, 40, 41, and 42. The voltages harmonics are assumed to be zero. The values of voltages, currents, powers and losses at various buses are calculated using the equations of conventional load flow.

4. Result and Analysis

Description of distribution network

The two algorithms in this work, namely, RDPF, and PSO, were implemented in matlab computing environment. The developed algorithms were tested on unbalanced-25-bus radial distribution system (URDS) whose single line diagram.

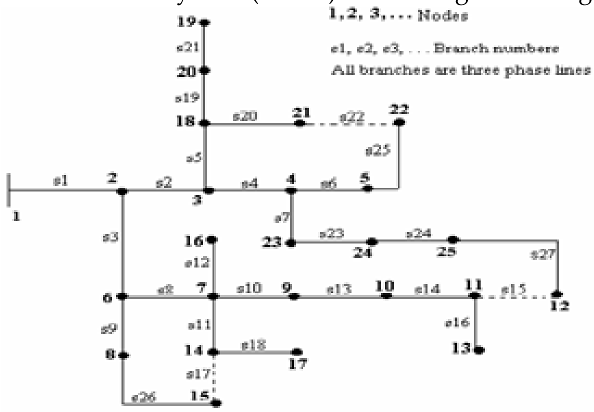

Fig2. Single line diagram of 25 bus URDS

The unbalanced-25-bus-RDS consists of different types of three phase lines and loads respectively. The system load is assumed as constant power load. The only supply source in the system is the substation at bus 1. Bus 1 is treated as a slack bus with a constant voltage on each phase of its three phases. The other buses (2-25) are modeled as pq constant buses. The loads at different buses is shown in table the lines are of three types and their impedances are:

Type1=[0.3686 + j*0.6852 0.0169 + j*0.1515 0.0155 + j*0.1098
0.0169 + j*0.1515 0.3757 + j*0.715 0.0188 + j*0.2072
0.0155 + j*0.1098 0.0188 + j*0.2072 0.3723 + j*0.6782];

Type2= [0.9775 + j*0.8717 0.0167 + j*0.1697 0.0152 + j*0.1264
0.0167 + j*0.1697 0.9844 + j*0.8654 0.0186 + j*0.2275
0.0152 + j*0.1264 0.0186 + j*0.2275 0.9810 + j*0.8648];

Type3 = [1.9280 + j*1.4194 0.0161 + j*0.1183 0.0161 + j*0.1183
0.0161 + j*0.1183 1.9308 + j*1.4215 0.0161 + j*0.1183
0.0161 + j*0.1183 0.0161 + j*0.1183 1.9337 + j*1.4236];

The loadings at different buses are listed in table:

Table1: Loading at different buses

Bus No	Phase A	Phase B	Phase C
1	0	0	0
2	35+j*25	40+j*30	45+j*32
3	50+j*40	60+j*45	50+j*35
4	40+j*30	40+j*30	40+j*30
5	40+j*30	45+j*32	35+j*25
6	0	0	0
7	40+j*30	40+j*30	40+j*30
8	60+j*45	50+j*40	50+j*35
9	35+j*25	40+j*30	45+j*32
10	45+j*32	35+j*25	40+j*30
11	50+j*35	60+j*45	50+j*40
12	35+j*25	45+j*32	40+j*30
13	50+j*35	50+j*40	60+j*45
14	133.3+j*100	133.3+j*100	133.3+j*100
15	40+j*30	40+j*30	40+j*30
16	40+j*30	35+j*25	45+j*32
17	40+j*30	40+j*30	40+j*30
18	60+j*45	50+j*35	50+j*40
19	35+j*25	40+j*30	45+j*32
20	40+j*30	35+j*25	45+j*32
21	50+j*35	60+j*45	50+j*40
22	60+j*45	50+j*40	50+j*35
23	35+j*25	45+j*32	40+j*30
24	60+j*45	50+j*30	50+j*35

The MVA base value is 30 and the line base voltage is the same as the feeder nominal voltage 4.16KV. The bus voltage are to kept within 10% of the nominal voltages throughout the optimization process.

The simulation is done for two different cases: it has suggested 9 locations For case1 and 23 locations for case 2

Case1: loss sensitive factors at each bus are evaluated without considering harmonics. The sequence of capacitances is given as
14b, 11b, 11c, 15c, 15a, 11a, 12b, 12c, 12a.

Case2: loss sensitive factors at each bus evaluated with considering harmonics. The sequence of capacitances is given as
13c, 17c, 13b, 17b, 17a, 10b, 14b, 10c, 14c, 14a, 10a, 16c, 11b, 16a, 11c, 15b, 15c, 15a, 16b, 11a, 12b, 12c, 12a.

Table2 loss sensitive factor at different buses for cases 1, 2

IJSER

ISSN 2229-5518

Bus no.	Without harmonics Lsf *10^3	With harmonics Lsf *10^3
1a	6.5932	6.6427
1b	6.8152	6.8704
1c	6.7379	6.7908
2a	1.5724	1.5842
2b	1.5952	1.6082
2c	1.5744	1.5868
3a	0.7785	0.7843
3b	0.7619	0.7681
3c	0.7027	0.7082
4a	0.3351	0.3376
4b	0.3387	0.3414
4c	0.3370	0.3396
5a	4.6591	4.7151
5b	4.8441	4.9064
5c	4.8211	4.8812
6a	4.0314	4.0907
6b	4.1911	4.2568
6c	4.2505	4.3152
7a	0.6715	0.6802
7b	0.6787	0.6881
7c	0.6755	0.6846
8a	1.8384	1.8671
8b	1.9747	2.0075
8c	1.9077	1.9385
9a	1.3326	1.3540
9b	1.5218	1.5477
9c	1.5139	1.5390
10a	0.6298	0.6399
10b	0.7069	0.7190
10c	0.6894	0.7008
11a	0.3153	0.3203
11b	0.4082	0.4151
11c	0.3626	0.3686
12a	0.2252	0.2288
12b	0.2902	0.2951
12c	0.2719	0.2764
13a	1.8724	1.9016
13b	1.8940	1.9255
13c	2.0223	2.0549
14a	0.6821	0.6929
14b	0.6900	0.7017
14c	0.6868	0.6980
15a	0.3391	0.3440
15b	0.3429	0.3483
15c	0.3413	0.3464
16a	0.4032	0.4095
16b	0.3380	0.3436
16c	0.4328	0.4398
17a	1.8435	1.8570
17b	1.8633	1.8781
17c	1.9554	1.9704
18a	0.7962	0.8019
18b	0.6223	0.6272
18c	0.7113	0.7167
19a	0.7836	0.7894
19b	0.7355	0.7413
19c	0.8108	0.8170
20a	1.1487	1.1570
20b	1.2435	1.2532
20c	1.2792	1.2888
21a	0.6194	0.6238
21b	0.8006	0.8069
21c	0.7116	0.7170
22a	1.0293	1.0370
22b	0.9227	0.9302
22c	0.9000	0.9070
23a	0.6275	0.6322
23b	0.5618	0.5663
23c	0.5859	0.5904
24a	0.7969	0.8028
24b	0.5339	0.5381
24c	0.6227	0.6275

Table3 Capacitor injections at different locations without harmonics

Capacitor locations	Reactive power(kvar)
14b	63.549
11b	10.995
15a	80.007
11c	168.762
15c	47.367
11a	240.315
12b	126.89
12c	181.527
12a	93.456

Total reactive power injection without harmonics=1012.868 kvar

IJSER

Table 4 capacitor injections at different locations with harmonics

Capacitor locations	Reactive power(kvar)
14c	147.18
14b	200.313
14a	145.989
10b	233.061
10c	159.912
10a	123.261
15b	73.743
15c	56.658
15a	61.653
11c	92.46
11b	190.872
11a	219.633
17c	95.901
12b	70.926
17a	221.34
12c	227.539
16b	80.289
16c	279.753
16a	117.783
17b	25.194
12a	152.481
13b	121.668
13c	116.961

Total reactive power injection without harmonics=3214.57kvar

Table 5 voltage at different buses for case 1 to4

	Without considering harmonics		With considering harmonics	
Bus no.	Voltages before compensation	Voltages after compensation	Voltages before compensation	Voltages after compensation
1a	1.000	1.0000	1.0000	1.0000
1b	1.000	1.0000	1.0000	1.0000
1c	1.000	1.0000	1.0000	1.0000
2a	0.9846	0.9873	0.9809	0.9837
2b	0.9832	0.9860	0.9793	0.9821
2c	0.9837	0.9867	0.9800	0.9819
3a	0.9809	0.9839	0.9774	0.9804
3b	0.9793	0.9826	0.9754	0.9783
3c	0.9800	0.9830	0.9762	0.9783
4a	0.979	0.9822	0.9756	0.9788
4b	0.9774	0.9809	0.9736	0.9765
4c	0.9782	0.9814	0.9745	0.9766
5a	0.9788	0.9819	0.9752	0.9784
5b	0.9770	0.9805	0.9732	0.9761
5c	0.9778	0.9810	0.9741	0.9762
6a	0.9786	0.9825	0.9729	0.9765
6b	0.9769	0.9797	0.9708	0.9751
6c	0.9775	0.9819	0.9716	0.9745
7a	0.9734	0.9784	0.9665	0.9712

IJSER

7b	0.9714	0.9738	0.9640	0.9696
7c	0.9721	0.9779	0.9649	0.9687
8a	0.9778	0.9819	0.9716	0.9745
8b	0.9760	0.9791	0.9694	0.9744
8c	0.9767	0.9812	0.9703	0.9731
9a	0.9710	0.9765	0.9637	0.9685
9b	0.9688	0.9714	0.9610	0.9671
9c	0.9696	0.9759	0.9620	0.9662
10a	0.9693	0.9749	0.9617	0.9664
10b	0.9668	0.9692	0.9588	0.9652
10c	0.9676	0.9744	0.9599	0.9644
11a	0.9684	0.9742	0.9609	0.9658
11b	0.9659	0.9680	0.9579	0.9644
11c	0.9668	0.9737	0.9590	0.9637
12a	0.9681	0.9739	0.9606	0.9655
12b	0.9655	0.9677	0.9575	0.9641
12c	0.9664	0.9731	0.9587	0.9634
13a	0.9682	0.9737	0.9607	0.9656
13b	0.9656	0.9670	0.9576	0.9642
13c	0.9665	0.9735	0.9588	0.9634
14a	0.9710	0.9764	0.9637	0.9695
14b	0.9689	0.9716	0.9611	0.9677
14c	0.9695	0.9760	0.9619	0.9663
15a	0.9702	0.9758	0.9627	0.9691
15b	0.9680	0.9710	0.9601	0.9671
15c	0.9686	0.9753	0.9609	0.9656
16a	0.9730	0.9782	0.9661	0.9709
16b	0.9709	0.9725	0.9636	0.9693
16c	0.9716	0.9777	0.9644	0.9683
17a	0.9706	0.9761	0.9633	0.9693
17b	0.9685	0.9714	0.9608	0.9674
17c	0.9690	0.9757	0.9615	0.9659
18a	0.9786	0.9818	0.9751	0.9785
18b	0.9768	0.9806	0.9731	0.9761
18c	0.9775	0.9809	0.9739	0.9761
19a	0.9769	0.9803	0.9735	0.9770
19b	0.9752	0.9793	0.9715	0.9746
19c	0.9759	0.9794	0.9723	0.9746
20a	0.9777	0.9810	0.9742	0.9777
20b	0.9759	0.9798	0.9721	0.9752
20c	0.9765	0.9799	0.9729	0.9751
21a	0.9775	0.9808	0.9740	0.9775
21b	0.9756	0.9797	0.9719	0.9750
21c	0.9763	0.9798	0.9727	0.9750
22a	0.9768	0.9802	0.9734	0.9770
22b	0.9749	0.9791	0.9712	0.9744
22c	0.9756	0.9792	0.9721	0.9744
23a	0.9780	0.9811	0.9744	0.9777
23b	0.9762	0.9798	0.9724	0.9754
23c	0.9770	0.9803	0.9733	0.9755
24a	0.9772	0.9804	0.9737	0.9771
24b	0.9754	0.9792	0.9716	0.9746
24c	0.9763	0.9796	0.9726	0.9748
25a	0.9764	0.9797	0.9730	0.9765
25b	0.9747	0.9786	0.9710	0.9740
25c	0.9756	0.9790	0.9720	0.9742

The below figures shows Voltage versus bus number or different phases of 25 bus URDS for considering harmonics and compensation of various combinations.

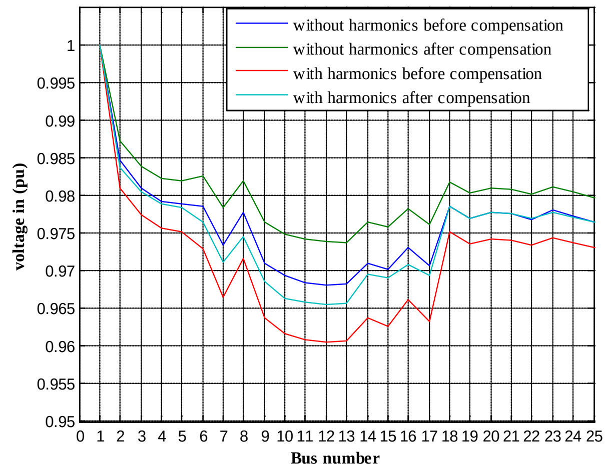

Fig.3 voltage at phase a of 25bus URDS

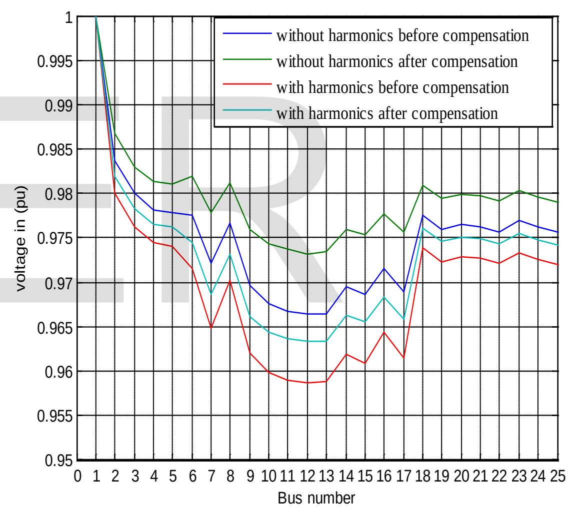

Fig.4 voltage at phase b of 25bus URDS

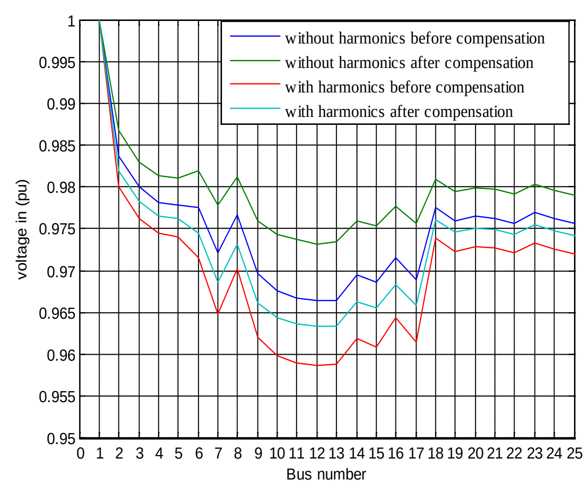

Fig.5 voltage at phase c of 25bus URDS

Losses

	Active losses(KW) in phases			Reactive losses(KW) In phases		
	A	B	C	A	B	C
Before compensa-tion without harmonics	15.60	16.49	16.52	22.42	22.59	22.8
After com-pensation without harmonics	11.84	5.16	5.472	16.61	16.56	16.73
Before compensa-tion with harmonics	23.85	24.65	24.68	33.45	33.53	33.88
After com-pensation with har-monics	17.62	13.97	12.68	22.60	17.73	23.43

Conclusion:

In this paper, the PSO based algorithm was tested on an 25-bus system to find the optimal locations of shunt capacitors taking harmonics into account. The objective function was to minimize the total real power losses of the system. PSO gives active power losses with lesser value of capacitive compensation. PSO method gives better reduction in power loss when compared with other compensation techniques.

References:

1. JEN-HAO TENG, “A Network- Topology based Three-Phase Load flow for Distribution systems”, Vol.24, No.4, 2000, Pp. 259-264.
2. GRAINGER, J. J.—LEE, S. H. : Optimum Size and Location of Shunt Capacitors for Reduction of Losses on Distribution Feeders, IEEE Trans. On Power Apparatus A. Syst. PAS-100
3. Three-phase Distribution Systems with Nonlinear and Unbalanced Loads, IEE Proc.-(1981),1105–1118 Radial Distribution System”, IEEE Trans. Power Delivery, vol. no.1, pp.1105-1117, Jan. 1989.
4. M. E. Baran and F. F. Wu, “Optimal Capacitor Placement on radialdistribution system,” IEEE Trans. Power Delivery, vol. 4, no.1, pp. 725-734, Jan. 1989.
5. Kennedy, and R.C. Eberhart, “Particle swarm optimization.”, proc. Int. conf. on neutral networks, Perth, Australia, pp.1942- 1948, 1995.
6. Sundharajan and A. Pahwa, “Optimal selection of capacitors for radial distribution systems using genetic algorithm,” IEEE Trans. Power Systems, vol. 9, No.3, pp.1499-1507, Aug. 1994.
7. Yamille del Valle, Ganesh Kumar Venayagamoorthy, Salman Mohagheghi, Jean-Carlos Hemandez and Ronald G. Harley, “Particle Swarm Optimization: Basic Concepts – Variants and Applications in power systems”, IEEE Transactions on Evolutionary Computation, Vol. 12, No. 2, April 2008,pp.178-195.
8. Abdelsalam A.Eajal,Student Member,IEEE, and M.E.El-Hawary,Life Fellow, IEEE, “Optimal Capacitor Placement and Sizing in Unbalanced Distribution Systems with Harmonics Consideration Using Particle Swarm Opti mization”, IEEE transactions on power delivery, vol. 25, no. 3, pp. 1734-1741,July 2010
9. A.A.Eajal and M.E. Elhawary, “Optimal capacitor placement and sizing in unbalanced distribution system with harmonics consideration using particle swarm optimization,” IEEE Trans. Power Delivery, Vol.. 25, No.3,July 2010
10. Y. Shi and Eberhart, “ Empirical study of particle swarm optimization,” pro. IEEE,Int. conf E.Vol. Comput.,pp.1945-1950,1999.
11. H.D. Chinag, J.C. Wang. O. cockings and H.D.Shin, “Optimal capacitor placements in distribution systems,” IEEE PES Summer Meeting, Long Beach,CA ,July9-13, 1989, paper# 89, SM 766-7 PWRD.
12.Ramon. .A. Gallego and etc,”Optimal capacitor placement in radial distribution, “ IEEE Trans, on power systems vol. 16, no.4, november2001.
13. A.Seifi, M.R.Hesamzadeh, "A Hybrid Optimization Approach for Distribution Capacitor Allocation Considering Varying Load Conditions," Elsevier Ltd., Electrical Power and Energy Systems, 2009. (Article in press).
14. Y. Baghzouz,” Effects of Nonlinear Loads on Optimal Capacitor Placement In Radial Feeders”, IEEE Transactions on Power Delivery, Vol. *6*, No. 1, January 1991.
15. B.Mirzaeian Dehkordi, M.Moallem et.al.,” Optimal Capacitor Placement and Sizing in TABRIZ Distribution System Using Loss Sensitivity Factors and Particle Swarm Optimization (PSO)”2012 Proceedings of 17th Conference on Electrical Power Distribution,Year: 2012,Pages:1-6.
16. L. Mohammadian; A. Mohammadian et.al., “Using a Hybrid Evolutionary Method for Optimal Planning, and Reducing Loss of Distribution Networks”, 16th Electrical Power Distribution Conference, Year: 2011,Pages: 1 – 9.
17. Soma Biswas, Swapan Kumar Goswami et.al.,” Optimal distributed generation placement in shunt capacitor compensated distribution systems considering voltage sag and harmonics distortions ”, Published in IET Generation, Transmission & Distribution, on 14th November 2013.
18. Leila Mohammadian, Mehrdad Tarafdare Hagh et.al., “Using PSO for Optimal Planning, and Reducing Loss of Distribution Networks”, 2012 Proceedings of 17th Conference on Electrical Power Distribution,Year: 2012,Pages:1-6.