International Journal of Engineering Research and Modern Education (IJERME)
Impact Factor: 6.525, ISSN (Online): 2455 - 4200
(www.rdmodernresearch.com) Volume 2, Issue 2, 2017

ENHANCED PARTICLE SWARM OPTIMIZATION (PSO) ALGORITHM FOR REACTIVE POWER OPTIMIZATION IN THE DISTRIBUTION SYSTEM

Meseret Yenesew
Electrical & Computer Engineering, Mizan-Tepi University, Ethiopia

Cite This Article: Meseret Yenesew, "Enhanced Particle Swarm Optimization (PSO) Algorithm for Reactive Power Optimization in the Distribution System", International Journal of Engineering Research and Modern Education, Volume 2, Issue 2, Page Number 56-64, 2017.

Abstract:

The problem of optimal capacitor allocation in electric distribution systems involves maximizing energy utilization, feeder loss reduction, and voltage profile improvement. The feeder loss can be separated into two parts based on the active and reactive power loss components. This paper presents an optimization method for minimizing the loss associated with the reactive component of branch currents by allocating optimal reactive power in the distribution system. In this paper, particle swarm optimization (PSO) algorithm is used for reactive power optimization problem in the distribution system. To allocate reactive power control variables in optimal location and with proper size two solution methods are applied. In the first method successive loss sensitive factor and normalized voltage is used to select the candidate optimal location of the capacitor and in the second method particle swarm optimization is applied to determine the size of capacitors at the optimal buses determined in part one. The performance of the proposed method is applied on 25 and 40 bus radial distribution feeders of town. Backward forward sweep load flow analysis also carried out for the purpose of total loss and bus voltage magnitude determination of the system. By applying the proposed method 22.5KW and 19.83KW of power is save for Ghion and Bata feeders respectively. This method gives better result than step by step loss reduction technique.

Key Words: Particle Swarm Optimization, Shunt Capacitor Placement & Successive Loss Sensitivity Factor.

1. Introduction:

The power system reactive power optimization problem result directly influences the power system stability and power quality. The reactive power can be controlled in order to improve the voltage profile and minimize the system loss. Generally, some load bus voltage might violate their upper or lower limits during system operation due to disturbances and/or system configuration changes. The power system operator can alleviate this situation and voltages can be maintained within their permissible limits by reallocating reactive power generation in the system.

The reactive power optimization problem is a nonlinear combinatorial optimization problem over the last decades the most conventional methods are linear programming and nonlinear programming. Recently artificial intelligence has been used for reactive power optimization such as genetic algorism, fuzzy logic, and others. The linear programming (LP) based technique is used to linearize the nonlinear power system optimization problem, so that objective functions and constraints of power system optimization have linear forms. It is advantageous because it is reliable, it can quickly identify infeasibilities and it accommodates a large variety of power system operating limits. The disadvantages of LP are inaccurate evaluation of system losses and insufficient ability to find an exact solution [27].

2. Literature Review:

Capacitors have been commonly used to provide reactive power compensation in distribution systems. They are provided to minimize power and energy losses, maintain best voltage regulations 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 essentially determination of the location, size, number and type of capacitors to be placed in the system[14]. Since, the optimal reactive power is a complicated combinatorial optimization problem, many different optimization techniques and algorithms have been proposed in the past.

B. Bhattacharyya, S. K. et al.[4] have applied hybrid fuzzy particle swarm optimization for solution of the reactive power problem. The purposes of this paper are to minimize real power loss and to improve the voltage profile of a given power system. They have used their method for optimal setting of transformer tap positions and reactive and to determine the location of shunt capacitors.

Ahmadreza Argha, et al. (2011*)* [9] have presented a paper on A novel fuzzy iterative learning control (FILC) for reactive power optimization in distribution systems. They have applied their method to determine the proper setting values and placing of capacitor banks. Simulation results are investigated on 9 bus system.

M. Rouholamini, et al. (2012)[11] have applied simulated Annealing Algorithm for optimal placement of reactive power sources for the purpose of Loss Minimization and voltage profile improvement. They have used their method to define the number of static reactive power generating units and to determine their optimal position in a radial network. The method is applied on "sedasima".

Yoshikazu Fukuyama, et al. (2001) [10] have applied particle swarm optimization (PSO) for reactive power and voltage control. They have applied their method to determines volt/var control by setting the discrete and continuous control variables such as automatic voltage regulator ,operating values of generators, tap positions of on-load tap changer (OLTC) of transformers, and the number of reactive power compensation equipment and to formulate VVC as a mixed integer nonlinear optimization problem (MINLP). The simulation result give best result as compeered with reactive tabu search (RTS) and enumeration methods.

B. Mozafari, T. Amraee, et al. (2007)[12] have applied an Improved Particle Swarm Optimization algorithm (IPSO) for reactive power optimization. They have used their method to reduce the cost of reactive power procurement and energy losses. The feasibility of the method is tested over an IEEE30 bus system.

Vivek Kumar Jain, et al. (2012)[7] have applied Particle Swarm Optimization (PSO) algorithm for Reactive power optimization including voltage deviation in Power System. for the aim of power loss minimization and voltage profile improvement. The proposed method is used to set generators bus voltages, transformer tap positions and switch-able shunt capacitor banks.

H. Mantawy M. S. and Al-Ghamdi(2003)[1] have applied Particle Swarm Algorithm (PSO) for reactive power optimization. The objective of the proposed algorithm is to minimize the system active power loss. They have used their method for generator bus voltages, transformer tap positions and switch able shunt capacitor banks adjustment. This method has been applied to practical IEEE 6-bus system. The proposed algorithm shows better results as compared to previous work.

P. Aruna Jeyanthy1, and Dr. D. Devaraj (2011)[3] have applied hybrid particle swarm optimization for multi objective reactive power optimization with voltage stability enhancement problem. They have applied their method for the objectives of losses minimization and to maximize the voltage stability margin. The proposed method expands the original GA and PSO to tackle the mixed –integer non- linear optimization problem and achieves the voltage stability enhancement with continuous and discrete control variables. It is evaluated on the IEEE 30 and 57 bus system**.**

P. Aruna Jeyanthy and Dr. D. Devaraj (2010)[8]this paper is used an approach called genetic algorithm for solving the multi-objective reactive power dispatch problem in a power system. Loss minimization and maximization of voltage stability margin are objectives of this paper. Generator terminal voltages, reactive power generation of the capacitor banks and tap changing transformer setting are taken as the optimization variables. An improved genetic algorithm which permits the control variables to be represented in their natural form is proposed to solve this combinatorial optimization problem. The proposed method has been tested on IEEE 30 bus System.

B. Mirzaeian Dehkordi , et al. (2011)[22] have applied particle swarm optimization(PSO) and loss sensitivity factor for optimal capacitor placement in a radial distribution system with the objective of investment cost minimization , energy loss reduction and for voltage profile improvement. They have used their method to determine the optimal location and size of the capacitor. This method is tested on a 10 buses distribution system and applied on the all feeders of Roshanaei and Golestan regions of Tabriz Electric Power Distribution Company (Tabriz, Iran).the simulation result gives better than fuzzy logic.

M. Damodar Reddy and V. C. Veera Reddy (2008)[24] have applied fuzzy and particle swarm optimization for optimal capacitor placement on the primary feeders of the radial distribution network with the objective of power loss reduction and voltage profile improvement. They have applied their method to select the optimal location using fuzzy and to determine the optimal size of the capacitor using PSO. The proposed method is tested on 15-bus, 34-bus and 69-bus test systems.

Esmail Limouzade (2012)[23] has applied genetic algorithm(GA) and particle swarm optimization for capacitor placement in the radial distribution system. In this paper power loss reduction and voltage profile improvement are objectives .a two stage method is applied. He applied his method to identify the optimal location of the capacitor using GA and to determine the size of the capacitor using PSO. The proposed method is implemented on 34-bus system.

This paper presents a method to determine suitable location based on loss sensitive factor and sizing problem for loss minimization using particle swarm optimization algorithm for analysis in distribution systems. An algorithm is developed for optimal reactive power allocation while minimizing power loss and improving the voltage profile. The particle swarm algorithm has been coded as well as the power flow forward backward method using MATLAB.

3. Methodology:

3.1 Problem Formulation:

The main purpose of the reactive power optimization is to minimize the system real power Losses and improve voltage quality.

The two main equations according to Kennedy and Eberhardt (1995) are as follows:

$$v_i(\mathrm{I}+1)=w*v_i(\mathrm{I})+c_1*r_1*(pb_i-x_i)+c_2*r_2*(gb_i-x_i) \quad (1.1)$$

Inertia weight cognitive component social component:

x_i(I+1)=x_i(I)+v_i(I+1) (1.2)

Where: v_i-velocity for the particle i, w -is the inertia weight that controls the impact of previous velocity of particle on its current one.

I –is iteration

$c_{1\&}$ c_2-are positive constant parameters called acceleration coefficients that control the maximum step size, their range is [0, 4]

pb_i-the best previous position of the particle

x_i-the present position of the particle i

$r_{1\&}$ r_2-are uniformly distributed random variables; their range is [0, 1]

g_b-the best position between all particle in the population

3.2 Steps for Particle Swarm Optimization Technique:

The PSO technique for this study can be described in the following steps.

Step 1: Initialization: define all parameters and generate random n particles, each particle in the initial population is evaluated using the objective function f. In this study, the objective function is the power loss in the network, which will be calculated after running the back ward forward sweep load flow.

Step 2: Velocity updating: Using the global best and individual best, the i^{th} particle velocity in the d^{th} dimension in this study (integer problem) is updated according to Equation 1.1: From the previous equation I is the iteration number, i is the particle number and d is the d^{th} control variable. Then, check the velocity limits. If the velocity violated its limit, set it at its proper limit. The second term of the above equation represents the cognitive part of the PSO where the particle changes its velocity based on its own thinking and memory. The third term represents the social part of PSO where the particle changes its velocity based on the social-psychological adaptation of knowledge.

Step 3: Position updating: Based on the updated velocity, each particle changes its position according to equation 1.2:

Step 4: Individual best updating: each particle is evaluated and updated according to the update position

Step 5: global best updating

Step 6: Stopping criteria: if the stopping criteria is satisfied, then stop otherwise go to step-2.

3.3 Data and Analysis:

We selected one town, which incorporates many industrial and commercial sectors. The loads mainly supplied from three substations There are one 400/230 kV substation (substation III), one 132/230/15kV and 230/66/15kV substation (substation II) and one 66/45/15kV substation (substation I), which supplies the town. The particular town distribution network consists of seven radial feeders, of these four (Airforce, Bata, Gion and Papyrus) feeders are from substation II and the rest three (Sematate, Boiler and Industry) feeders are from substation I. We need to release the power flow in transmission lines for partially solving of problem of losses as well as other problems. We can't do anything with active power flow, but we could supply the reactive power locally where it is highly consumed in a system. In this way the loading of lines would decrease. It would decrease the losses also and with this action the problem of voltage drops could be solved also. To do so the data needed for this research work are collected from different sources.The overhead conductors' parameters are given in Table 3.1.

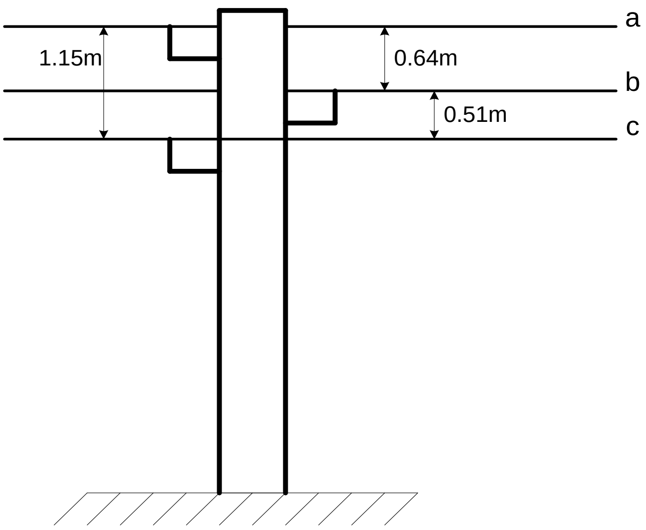

Figure 1.1: Over head conductor arrangement

Table 1.1: Over head medium voltage conductor size

Conductor type	Nominal area (mm^2)	Actual area (mm^2)	Stranding and wire diameter	Overall diameter (mm)	Actual diameter (mm)	GMR (mm)	Resistance (Ω/km)
AAC	50	49.48	7/3.00	9.0	7.9377	2.88	0.5785
AAC	95	93.27	19/2.5	12.5	10.8975	4.129	0.3085

3.3 Optimal Location and Size of Reactive Power Control variable on Radial Distribution Feeders Using PSO:

Optimization is the act of obtaining the best result under given circumstances. In design, construction, and maintenance of any engineering system, engineers have to take many technological and managerial decisions at several stages. The ultimate goal of all such decisions is either to minimize the effort required or to maximize the desired benefit. Since the effort required or the benefit desired in any practical situation can be expressed as a function of certain decision variables, optimization can be defined as the process of finding the conditions that give the maximum or minimum value of a function.PSO is one method of optimization to minimize real power loss of distribution network. As I have described in the introduction part from the total loss in the system more loss is wasted in the distribution level. The Portion of this loss is caused by the reactive current flowing in the network. It can be considerably reduced through the installation and control of reactive support equipments, such as shunt capacitor banks, reducing reactive currents flowing in distribution feeders and reactive power optimization. Capacitors are widely installed in distribution systems for reactive power compensation to achieve power and energy loss reduction, power factor correction, system capacity release and to maintain a voltage profile within permissible limits [17].

3.4.1 Selection of Capacitor Location:

In this paper successive loss sensitivity analysis is used to select the candidate node for optimal shunt capacitor placement and to place it more than one place. In order to reduce the search space it is a priori to select the best place(s) in the system. Loss sensitivity approach can be used for the purpose which is described in [18]. Accordingly, the total power loss against injected power is a parabolic function and at minimum loss the rate of change of loss with respect to injected power becomes zero.

$$\frac{\partial PL}{\partial pi} = 2 * \sum_{j=1}^{N} (\alpha ijPj - \beta ijQj) \quad (1.3)$$

Where:

PL is the real power loss;

$Z_{ij} = r_{ij} + jx_{ij}$; ijth element of $[ZBUS]$ matrix and the loss coefficients

$$\alpha ij = r_{ij} \cos(\delta i - \delta j)/V_i * V_j \quad (1.4)$$

$$\beta ij = r_{ij} \sin(\delta i - \delta j)/V_i * V_j \quad (1.5)$$

Based on the above equation and by writing MATLAB code for $ZBUS$ building algorism after running the MATLAB program the value of α , β and loss sensitivity factor are obtained and the values are arranged in descending order for all the lines of the given system. The values of the LSF are arranged in their descending order. The descending order of the loss sensitivity factor determines the sequence in which the buses are to be considered for optimization.

Normalized voltage magnitudes are calculated by considering the base case voltage magnitudes given as below.

$$\text{Norm}[i] = |V[i]|/0.95 \quad (1.6)$$

Where:

V[i] is the base voltages of the corresponding bus.

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 candidate buses are stored in “candidate bus” vector. It is to be noted that the “Loss Sensitivity Factors” decide the sequence in which buses are to be considered for capacitor placement and norm[i] decides whether the buses needs Q-compensation or not. If norm[i] is greater than 1.01 such bus needs no compensation and that bus will not be listed in “candidate bus” vector. The “candidate bus” vector gives the information about places for the capacitor placement.

3.4.2 Selection of Capacitor Size:

The implementation of particle swarm optimization algorithm for reactive power optimization consists mainly of identification objective and handling of constraints. The control variable selected for reactive power optimization of this thesis is reactive power generated by the capacitor.PSO algorithm is employed to find the best control setting starting from a randomly generated initial population of control variables this best value of the algorithm will be the size of the capacitor to be install in the selected location of the distribution network.

4. Results and Discussion:

Reactive power optimization process is applied on two feeders of town 400/230/132/66/15kv distribution feeder. These feeders are Ghion and Bata which have 25 and 40 buses respectively. Based on the collected data that are give in Table 4.3 and Table 4.4 backward forward sweep load flow is running. From this we get the initial power loss of the feeder and bus voltage. Initially the total loads of 25 buses are 1.423MW and 1.1106Mvar and for 40 buses the total loads are 1.77MW and 1.47Mvar in addition to this the initial loss of the feeder is 0.0558MW and 0.0578MW for 25 and 40 buses system respectively. The particle swarm optimization based reactive power optimization problem was implemented using MATLAB R2008a programming language on 2.3 GHZ processer and 3.46GB installed memory (RAM) PC. Based on the flowchart given in Section 4.2 MATLAB code was executed on a PC. The proposed algorithm was run for minimization of real power loss as the objective function. To obtain the optimal values of the control variables, the PSO based algorithm was run with different optimal control settings. The parameters used are the following.

- ✓ Population size :30
- ✓ w_{max} : 0.9
- ✓ w_{min} :0.4
- ✓ C_1 : 2
- ✓ C_2 : 2

The results of the two feeders will be discussed below.

Table 1.2: Result of PSO Algorithm for 25 Buses

MATLAB Run	Capacitor size (Kvar)		Loss (KW)
	Bus 17	Bus 19	
1	667	100.1	33.3014
2	671.3	193.3	33.3016
3	782	82.6	33.3502
4	856.6	12	33.4266
5	138.4	704.4	34.1968
6	547.4	301.7	33.3409
7	69.3	785.9	34.4988
8	717.3	153.5	33.3106
9	417.3	411.9	33.4816
10	730.9	141.2	33.3157
11	545.2	301.1	33.3423
12	761.7	195.4	33.3366
13	184.6	612.4	33.989
14	822.2	61.6	33.3787
15	447.5	416.3	33.4639
16	811.7	71.7	33.3689
17	510.2	353	33.3824
18	555.3	292.4	33.3355
19	397.8	421.9	33.5125
20	619.6	242.9	33.3075

Table 1.3: Load flow solution of 25 buses after optimization

Bus Number	Voltage magnitude (pu)	Line loss(KW)	Bus Number	Voltage magnitude(p.u)	Line loss(KW)
1	1.000	0	14	0.9829	0.0350
2	0.9939	12.2244	15	0.9828	0.1381
3	0.9932	1.6292	16	0.9881	1.4312
4	0.992	3.1656	17	0.9884	0.2759
5	0.9895	6.1985	18	0.9884	0.1303
6	0.988	3.9283	19	0.9886	0.2016
7	0.9878	0.54	20	0.9884	0.0502
8	0.9869	2.5718	21	0.9881	0.0194
9	0.9939	0.0015	22	0.9883	0.0179
10	0.9879	0.0064	23	0.9882	0.0186
11	0.9877	0.0075	24	0.9878	0.0185
12	0.9835	1.728	25	0.9877	0.0005
13	0.9832	0.0481			

Total loss (KW)	33.3

Table 1.4: Result of PSO algorithm for 40 buses

MATLAB Run	Capacitor size (Kvar)		Loss(KW)
	Bus 33	Bus 38	
1	733.2	197.9	37.975
2	718.6	214.8	37.9715
3	761.5	182.4	37.985
4	320.2	517.7	38.7357
5	691	240	37.9732
6	170.7	706	39.5893
7	763.6	182.2	37.9862
8	669.5	261.6	37.9814
9	772.7	155.4	38.0009
10	671.7	259.5	37.9803
11	713	219.8	37.9712
12	672.8	258.4	37.9798
13	515	369	38.1602
14	440	493.9	38.4612
15	593.9	337.3	38.0591
16	675.5	247.5	37.9767
17	110.4	659.3	39.7965
18	698.9	230	37.9716
19	698.1	230.4	37.9717
20	685.4	240	37.9739

Table 1.5: Load flow solution of 40 buses after optimization

Bus Number	Voltage magnitude (p.u)	Bus Number	Voltage magnitude (p.u)
1	1.000	21	0.9812
2	0.9888	22	0.9802
3	0.9855	23	0.9797
4	0.9844	24	0.9795
5	0.984	25	0.9793
6	0.983	26	0.9793
7	0.9817	27	0.9799
8	0.9811	28	0.9795
9	0.9811	29	0.9792
10	0.9876	30	0.9788
11	0.984	31	0.9784
12	0.9829	32	0.9783
13	0.9816	33	0.9796
14	0.9809	34	0.9789
15	0.9806	35	0.9787
16	0.9815	36	0.9786
17	0.9804	37	0.9796
18	0.9799	38	0.9778
19	0.9795	39	0.9771
20	0.9792	40	0.9765
Total loss(KW)	37.97		

The reduced loss is shown in Figure below.

Figure 1.2: Line loss of 25 bus system

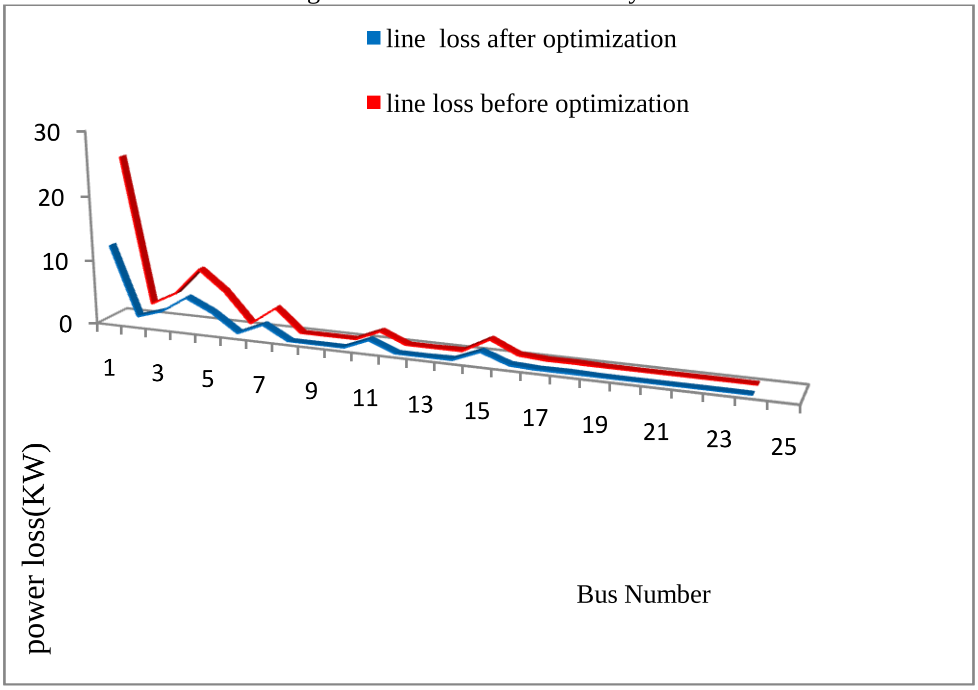

Figure 1.3: Line loss of 40 bus system

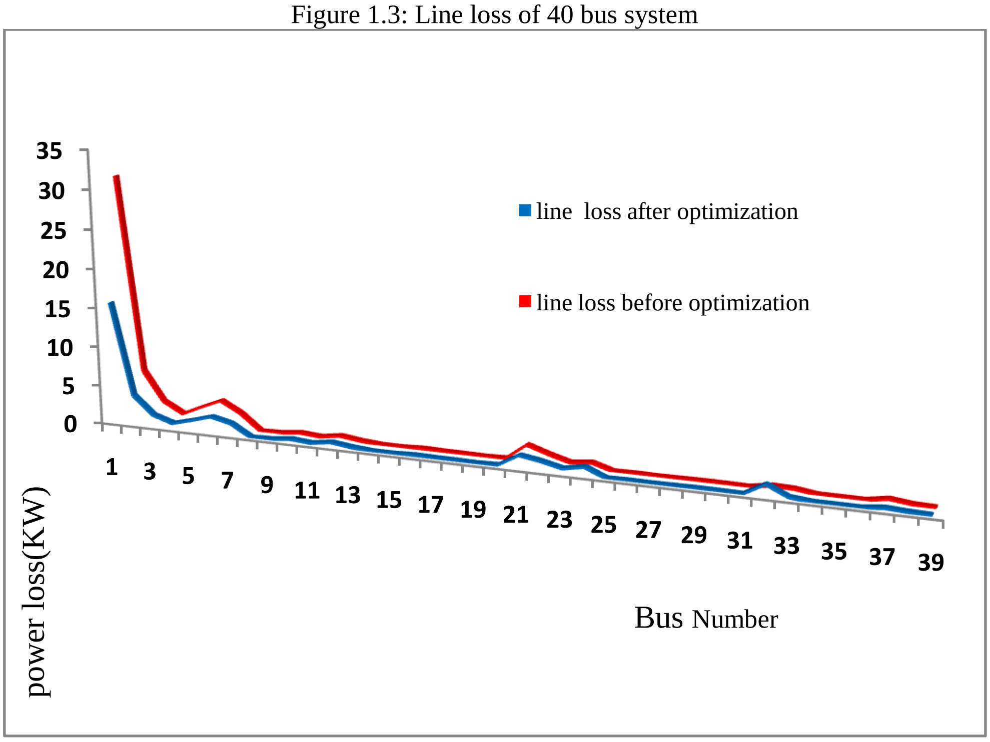

Table 1.6: Result summary of two buses

Feeder type	Description	Before optimization	After optimization
Ghion	Total line current (A)	161.9	120
	Released current(A)		42
	Total loss(KW)	55.8	33.3
	Maximum bus voltage(p.u)	0.9845	0.9939
	Minimum bus voltage(p.u)	0.9575	0.9881
	Cumulative voltage deviation(p.u)	0.831	0.401
Bata	Total line current (A)	212.8	180.4

	Released current(A)		32.4
	Total loss(KW)	57	37.97
	Maximum bus voltage(p.u)	0.9811	0.9888
	Minimum bus voltage (p.u)	0.9548	0.9765
	Cumulative voltage deviation(p.u)	1.345	0.753

Table 1.7: Result comparison between different methods

Method	Test bus system	Simulation software used	Optimal location	Optimal size(Kvar)	Loss (KW)	
					Before optimization	After optimization
Step by step loss reduction	25	POWER WORLD simulator	Bus 17 & 19	750 and 150	55.8	40
	40		Bus 33 & 38	750 and 300	57.8	40
Particle Swarm Optimization (This paper)	25	MATLAB code	Bus 17 & 19	750 and 100	55.8	33.3
	40		Bus 33 & 38	750 and 250	57.8	37.97

5. Conclusion and Recommendation:

In this paper 25 and 40 buses of radial distribution feeders are considered for analysis of reactive power optimization problem to determine the optimal location and size of capacitor banks. A method to determine suitable location based on loss sensitive factor and sizing problem for loss reduction using particle swarm optimization algorithm for analysis in distribution systems. An algorithm is developed for optimal reactive power allocation while minimizing power loss and improving the voltage profile. The results indicates that by applying the proposed method 22.5KW and 19.83KW power is saved and also voltage profile improvement achieved for Ghion and Bata feeders respectively, by this implies that PSO is an efficient method as compared to step by step loss reduction method for real power loss minimization and voltage profile improvement of a given distribution network. From the result the amount of loss reduced in particle swarm optimization gives better than step by step loss reduction method. The loss minimization using shunt capacitors reduces the current flowing in each section of the feeder and hence the voltage drop in the section is reduced. Therefore the voltage profile is improved after the feeder line is compensated and the quality of the power is improved. It is concluded that particle swarm optimization is efficient method to solve non linear optimization problems. Further researches can be done by including distributed generator (DG) in the distribution system, service restoration and feeder reconfiguration also considered in order to minimize the active power loss and to improve voltage profile.

6. References:

1. H. Mantawy M. S. Al-Ghamdi,"A New Reactive Power Optimization Algorithm", IEEE, Bologna power Tech conference, June 23.-26 2003.
2. Al-Mahroqi and et al, "Reduction of Power Losses in Distribution Systems", World Academy of Science, Engineering and Technology, 2012.
3. P. Aruna Jeyanthy1, and Dr. D. Devaraj," Hybrid Particle Swarm Optimization for Multi- objective Reactive Power Optimization with Voltage Stability Enhancement" ACEEE Int. J. on Control System and Instrumentation, Vol. 02, No. 02, June 2011.
4. B. Bhattacharyya, S. K. et al ,"Fuzzy Particle Swarm Optimization Approach for Reactive Power Optimization", International Journal on Electrical Engineering and Informatics, Volume 4, Number 2, July2012
5. N. Mancer, et al, "Multi Objective for Optimal Reactive Power Flow Using Modified PSO Considering TCSC**",** International Journal of Energy Engineering, pp 165-170, 2012.
6. Hongzhong Li, et al **,"** Reactive Power Planning based on Improved Particle Swarm Optimization with Static Voltage Stability" 18th International Conference on Electricity Distribution Turin, pp 6-9 ,June 2005.
7. Vivek Kumar Jain, et al.**, "**Minimization of Reactive Power Using Particle Swarm Optimization**",** International Journal of Computational Engineering Research**,** Vol. 2, Issue No.3, pp686-691, May-June 2012.
8. P. Aruna Jeyanthy1, and Dr. D. Devaraj, "Optimal Reactive Power Dispatch for Voltage Stability Enhancement Using Real Coded Genetic Algorithm", International Journal of Computer and Electrical Engineering, Vol. 2, No. 4, August, 2010.
9. Ahmadreza Argha et al., "Using Fuzzy ILC for Reactive Power Planning in Distribution Systems", World Applied Sciences Journal, ISSN 1818-4952, pp2263-2270, 2011.

10. Yoshikazu Fukuyama et al, ”A Particle Swarm Optimization for Reactive Power and Voltage Control Considering Voltage Security Assessment”, IEEE Trans. on Power Systems, Vol.15, No.4, pp.1232-1239, November 2001.
11. M. Rouholamini1 et al,” Optimal Placement of Reactive Power Sources for Loss Minimization and Voltage Profile Improvement”, World Academic Publishing, Vol. 1 No. 1, PP.1-5, 2012.
12. B. Mozafari, T. Amraee, A.M. Ranjbar and M. Mirjafari,” Particle Swarm Optimization Method for Optimal Reactive Power Procurement Considering Voltage Stability”, Scientia Iranica, Vol. 14, No. 6, pp 534-545, December 2007
13. M. B. Liu, et al ,” Reactive Power and Voltage Control in Distribution Systems with Limited Switching Operations”, IEEE Transactions on Power Systems, Vol. 24, No. 2, May 2009.
14. Miller, T.J.E, “Reactive Power Control in electric System”, New York, John wiley & Sons Inc, 1982.
15. U. Eminogluand M. H. Hocaoglu, "Distribution Systems Forward/Backward Sweep-based Power Flow Algorithms: A Review and Comparison Study", 11 Dec 2008.
16. Abdul Rahman, K.H. and Shahidehpour, “A fuzzy based optimal reactive power control “, IEEE Transactions on Power Systems, PP662-670, 1993.
17. Ramasamy Natarajan, 2005, Power System Capacitors, CRC Press.
18. O.I.Elgerd, “Electric energy system theory: an introduction” McGraw-Hill., 1971.
19. Rania Hassan, et al, “A Comparison of Particle Swarm Optimization and the Genetic Algorithm”, 2004.
20. A. Alsaadi, and B. Gholami, “An Effective Approach for Distribution System Power Flow Solution”, International Journal of Electrical and Electronics Engineering 3:12, 2009.
21. Paulo M. De Oliveira, “The Standard Backward/Forward Sweep Power Flow”, IEEE, 2008.
22. B. Mirzaeian Dehkordi, et al **“**Optimal Capacitor Placement and Sizing in Tabriz Electric Power Distribution System Using Loss Sensitivity Factors and Particle Swarm Optimization (PSO)” , Published by International Organization on TPE (IOTPE),Volume 3 ,Number 2 ,Pages 54-59, 2011.
23. Esmail Limouzade, “Optimal Placement of Capacitors in Radial Distribution System Using a GA-PSO method**”,** TASE 5(1), PP60-65, 2012.
24. M. Damodar Reddy and V. C. Veera Reddy, “Capacitor Placement Using Fuzzy and Particle Swarm Optimization Method For Maximum Annual Savings”, Vol. 3, NO. 3, June 2008.
25. W.N.W Abdullah and H. Saibon A.AM Zain, “Genetic Algorithm for Optimal Reactive Power Dispatch”, Proceedings of International Conference on Energy Management and Power Delivery, Vol. 1, pp. 160-164, Mar 1998.
26. L.Ramesh et al,” Minimization of Power Loss in Distribution Networks by Different Techniques”, International Journal of Electrical and Electronics Engineering , 3:9 ,2009.
27. Jizhong Zhu,” Optimization of Power System Operation”, John Wiley & Sons, Inc., Hoboken, New Jersey, CanadaIEEE, page 23.
28. Juan Luis, “Particle Swarm Optimization”, https://www.google.com.et/particle+swam+optimization +ppt