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Optimal Capacitor Placement in Distribution System

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ABSTRACT

This paper presents an approach that determines the optimal size and location of capacitor in radial distribution system for improvement of voltage profile and reduce loss. Capacitor sizing and siting are done by particle swarm optimization technique. Particle swarm optimization offer the important information about the sequence of potential node for siting of capacitor. Particle swarm optimization is well applied and found to be very effective in radial distribution systems. The proposed method is tested for 33 bus distribution system.
Keywords. Capacitor sizing, Capacitor placing, radial distribution system, Particle swarm optimization.

I. INTRODUCTION

As distribution systems are growing large and being expanded too far, leading to higher system loss and poor voltage regulation, the need for an efficient and effective distribution system as therefore become more important. On this regard, capacitor banks are added on radial distribution system for loss reduction and voltage profile improvement.

With this various objectives in view, optimal capacitor placement aims to determine capacitor location and its size. Researches has been carried out over decades on optimal capacitor placement. Early approaches were based on heuristic techniques. In the 80's, more rigorous approaches were suggested illustrated by Grainger[1],[2] and Baran Wu, [3] formulated the capacitor placement as a mixed integer non-linear program. In the 90's few algorithms were introduced as a means of solving the capacitor placement program. [4]Ng and Salama have proposed a solution approach to the capacitor placement problem based on fuzzy sets theory. Using this approach the authors tried to account for uncertainty in the parameter problems.

[5]determines the optimal capacitor sizing in order to increase the reliability and improve power quality by the particle swarm optimization algorithm in the distribution network. In [6], a fuzzy set theory is used for optimal placement of capacitor to reduce power losses in the radial distribution network. [7],has suggested a simple strategy for the capacitor placement problem and improve power quality based genetic algorithm, the objective function consists the cost of power losses and costs related to the capacitor banks.

Self adaptive harmony search algorithm for optimal capacitor placement to reduce power losses in the distribution network is provided in [8]. Improved Harmony search algorithm for optimal placement capacitor is used in radial distribution network in [9]. In [10], it is suggested a new adaptive modified firefly algorithm to solve the optimal capacitor placement problem, the objective function is composed of the power losses cost and cost of installing capacitors.

In [11],a particle swarm algorithm by considering the harmonic distortion for the capacitor placement is presented in radial distribution network. The objective function is combination of the capacitor costs and active losses costs. In [12], the PSO algorithm to solve this problem, with the aim of minimizing the losses in radial distribution network has been used.

Particle swarm optimization (PSO) was developed by James Kennedy and Russell Eberhart. It is based on metaphor of social interaction, searches a space by adjusting directions of moving points in a multi dimensional space and used for optimization of non-linear problems. The main advantages of the PSO are. simple concept, easy implementation quality to control parameters and good computational efficiency compared to other heuristic algorithms.

In this paper, capacitor siting and sizing is done by particle swarm optimization technique. PSO is used

for estimation of required level of shunt capacitive compensation to improve the voltage profile of bus system and the proposed method can successfully avoid premature convergence. The proposed method is tested on 33 bus radial distribution systems.

II. MATHEMATICAL MODEELLING

2.1 CONSTRAINTS.

In solving the optimal capacitor placement problem, the magnitude of voltage at each bus should be kept within its limits as follows

$$Vmin \leq |Vi| \leq Vmax$$

Where Vi is the voltage magnitude at bus I, Vmin is the minimum voltage limit and Vmax denotes the maximum voltage limit. The bus voltages can be obtained by using the iterative method of Newton Raphson.

2.2 POWER LOSS CALCULATION.

To calculate the power loss, Newton Raphson iterative technique has been employed

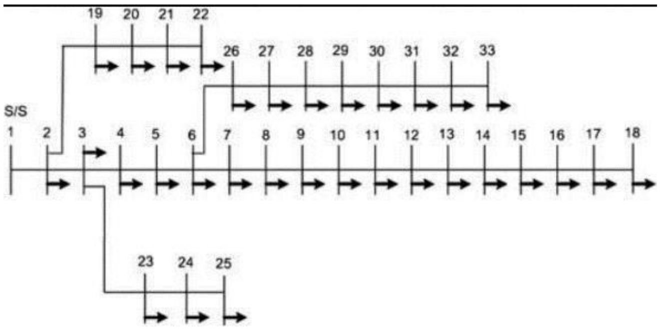


Figure 1. Single line diagram of 33bus system

Table 1. Line Data For Loss Calculation

FROM	TO	R	X	B	TRANSFORMER TAPPING
1.0000	2.0000	0.0922	0.0470	0.0000	1.0000
2.0000	3.0000	0.4930	0.4930	0.0000	1.0000
3.0000	4.0000	0.3661	0.3661	0.0000	1.0000
4.0000	5.0000	0.3811	0.3811	0.0000	1.0000
31.0000	32.0000	0.3105	0.3619	0.0000	1.0000
32.0000	33.0000	0.3411	0.5302	0.0000	1.0000

Table 2. Bus Data For Loss Calculation

US N O	BUS TYPE	VTG MAG.	ANGLE DEGREE	LOAD MW	LOAD MVAR	GENERATOR MW	GENERATOR MVAR	Qmin	Qmax	Injected MVAR
1	1	1	1	0	0	0	0	0	0	0
2	0	1	0	0.100	0.060	0	0	0	0	0
3	0	1	0	0.090	0.040	0	0	0	0	0
4	0	1	0	0.120	0.080	0	0	0	0	0
32	0	1	0	0.210	0.100	0	0	0	0	0
33	0	1	0	0.060	0.040	0	0	0	0	0

The line losses for the IEEE standard 33bus system as shown in fig 1 is calculated by Newton Raphson method by considering the above mentioned line data and bus data as input. The losses at each bus and total loss of bus system is calculated by Newton Raphson and the results of Newton Raphson are.

Table 3. Power Flow Solution By Newton Raphson Method

BUS NO	VTG MAG.	ANGLE DEGREE	LOAD MW	LOAD MVAR	GENERATOR MW	GENERATOR MVAR	Injected MVAR

1	1.000	0.000	0.000	0.000	3.917	2.434	0.000
2	0.997	0.014	0.100	0.060	0.000	0.000	0.000
3	0.983	0.096	0.090	0.040	0.000	0.000	0.000
4	0.975	0.162	0.120	0.080	0.000	0.000	0.000
32	0.917	0.388	0.210	0.100	0.000	0.000	0.000
33	0.917	0.380	0.060	0.040	0.000	0.000	0.000

III. PARTICLE SWARM OPTIMIZATION

Particle Swarm Optimization (PSO) is a meta heuristic parallel search technique used for optimization of continues non linear problems. The method was discovered through simulation of a simplified social model. PSO has roots in two main component methodologies perhaps more obvious are ties to artificial life in general, and to bird flocking, fish schooling and swarming theory in particular.

It is also related, how ever to evolutionary computation and has ties to both genetic algorithms and evolutionary programming. It requires only

primitive mathematical operators, and is computationally inexpensive in terms of both memory requirements and speed.

It conducts searches using a population of particles, corresponding to individuals. Each particle represents a Candidate solution to the capacitor sizing problem.

In a PSO system, particles change their positions by flying around a multi dimensional search space until

a relatively unchanged position has been encountered, or until computational limits are exceeded. In social science context, a PSO system combines a social and cognition models.

The general elements of the PSO are briefly explained as follows.

Particle X(t). It is a k-dimensional real valued vector which represents the candidate solution. For an ith particle at a time t, the particle is described as Xi(t)={Xi,1(t), Xi,2(t),… Xi,k(t)}.

Population. It is a set of ‘n’ number of particles at a time t described as {X1(t), X2(t)… Xn(t)}.

Swarm. It is an apparently disorganized population of moving particles that tend to cluster together while each particle seems to be moving in random direction.

Particle Velocity V(t). It is the velocity of the moving particle represented by a k-dimensional real valued vector Vi(t)= {vi,1(t), vi,2(t)…… vi,k(t)}.

Inertia weight W(t). It is a control parameter that is used to control the impact of the previous velocity on the current velocity.

Particle Best (pbest). Conceptually pbest resembles autobiographical memory, as each particle remembers its own experience. When a particle moves through the search space, it compares its fitness value at the current position to the best value it has ever attained at any time up to the current time. The best position that is associated with the best fitness arrived so far is termed as individual best or Particle best. For each Particle in the swarm its pbest. can be determined and updated during the search. **Global Best (gbest).** It is the best position among all the individual pbest of the particles achieved so far. **Velocity Updation.** Using the global best and individual best, the ith 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])). where,

- constriction factor

c1, c2 weight factors wInertia weight factor

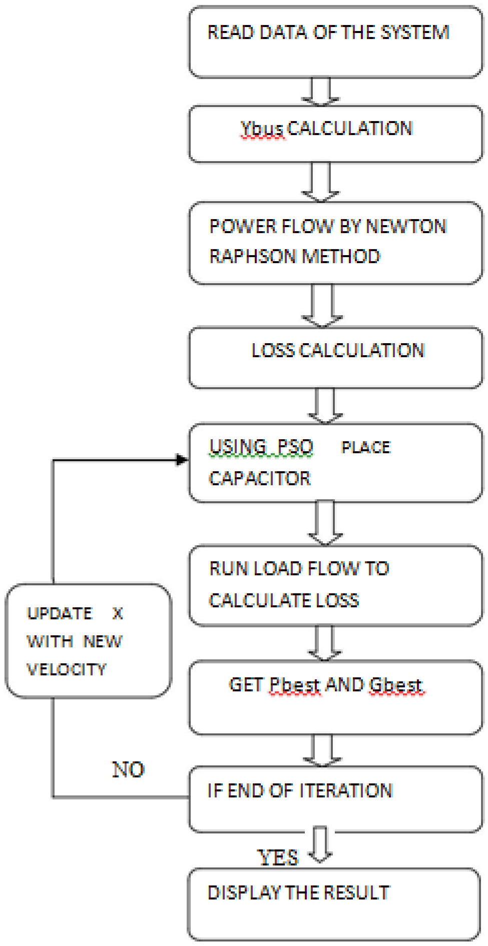
1. particle number
2. control variable

rand1, rand2 random numbers between 0 and 1

Stopping criteria. This is the condition to terminate the search process. It can be achieved either of the two following methods.

1. The number of the iterations since the last change of the best solution is greater than a pre-specified number.
2. ii. The number of iterations reaches a pre-specified maximum value.

IV. FLOW CHART



V. EXPERIMENTAL RESULTS

Matlab code is developed for the implementation of proposed technique. The results are obtained by applying the proposed method on a IEEE standard 33bus system.

For present work, the population of 40 swarms is taken. Iteration numbers are increased in steps and it is found optimal value is achieved with a minimal maximum iterations. Values of c1, c2 set at 2 experimentally.

Table 4 shows the simulation results without PSO

Table 4. Lineflow Losses Before Placement Of Capacitor

FROM	TO	POWER AT BUS		LINE FLOW	LINE LOSES	
		MW	MVAR		MW	MVAR
1		3.917	2.434	4.611		
	2	3.918	2.435	4.613	0.012	0.006
2		-0.100	-0.060	0.117		
	1	-3.905	-2.429	4.599	0.012	0.006
	3	3.444	2.208	4.091	0.052	0.026
	19	0.361	0.161	0.395	0.000	0.000
TOTAL LOSSES					0.203	0.135

Table 5. Lineflow Losses With Pso After Placing Capacitor

ITERATION NUMBER	OPTIMAL LOCATION	OPTIMAL SIZE(MW)	FINAL LOSS (MW)
1	27	0.9223	0.1048
2	6	2.000	0.1044
49	30	1.4486	0.0900
50	30	1.4486	0.0900
98	30	1.5068	0.0900
99	30	1.5068	0.0900
100	30	1.5068	0.0900

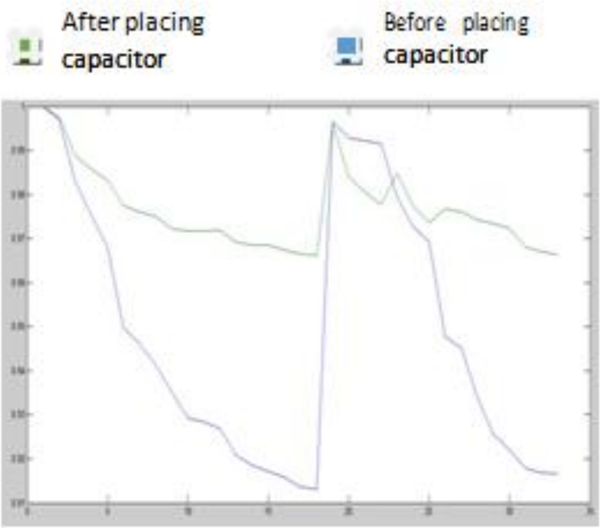


Figure 2. Improved voltage profile

Table 5. Siting And Sizing Of Capacitor After Pso

BEST PLACE	SIZE OF THE CAPACITOR	LOSESS
30	1.5068	0.0900

The proposed method for loss reduction by capacitor siting gives the results in the above tables. By comparing TABLE IV and TABLE V the loss reduction after placing capacitor can be seen. The improved voltage profile is shown in the fig 2. The best position for siting of capacitor and size of capacitor is tabulated in TABLE VI.

VI. CONCLUSION

In this paper, an algorithm that employs Particle Swarm Optimization, a meta heuristic parallel search technique for estimation of required level of shunt capacitive compensation to improve the voltage profile of the system and reduce active power loss.

The main advantage of this proposed method is that it systematically decides the locations and size of capacitors to realize optimum position for active power loss and significant improvement in voltage profile and premature convergence is overcome.

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