

# Reduction in Power Losses on Distribution Lines using Bionic Random Search Plant Growth Simulation Algorithm

Tanuj Manglani<sup>1</sup>, Y.S.Shishodia<sup>2</sup>

Assistant Professor, Department of Electrical Engineering, YIT, Jaipur, India

Pro. VC, JaganNath University, Jaipur, India

E-mail: [tdtanuj@gmail.com](mailto:tdtanuj@gmail.com)

**Abstract** - To reduce the losses in distribution systems, bionic random search algorithm has been proposed using optimal capacitor placement. The main advantage of the proposed method is that it does not require any external control parameters. The proposed method is implemented on IEEE 34 bus radial distribution system. The solutions obtained by PGSA give better result than fuzzy logic method.

**Index Terms** - Capacitor placement, capacitor sizing, optimal capacitor allocation, distribution system, power loss reduction, PGSA, Random search algorithm, Bionic search.

## I. INTRODUCTION

In the present scenario of energy crisis, saving of the power has become a major issue. Studies have indicated that as much as 13% of total power generated is wasted in the form of losses at the distribution level [1]. The reduction of losses in the power networks is much more beneficial than the increase of generating capacities. Losses can be reduced by connecting capacitors in shunt to locally supply a considerable portion of the reactive power demanded by the consumers and thereby reducing the reactive component of branch currents [2]. Therefore, it is important to find optimal location and sizes of capacitors in the system to reduce power losses. Various optimization techniques and algorithms have been proposed in the past to reduce the power losses such as algorithm based on analytical methods[3-4], numerical programming methods [5-6], heuristics methods [7-8], genetic algorithm [9-11], simulated annealing [12-13],fuzzy logic [14-15],PSO[16-17] and ant colony algorithm [18].

In this paper, power losses will be reduced by using capacitor placement with the help of Plant Growth Simulation Algorithm (PGSA). The proposed method is tested on 34 bus radial distribution systems.

## II. MULTI-OBJECTIVE OPTIMIZATION

The objective of capacitor placement is to reduce the power losses on the distribution system but to maintain the voltage regulation while keeping the cost of capacitor placement at a minimum. The power flow is computed using Newton Raphson method in MATLAB to calculate the total power loss of the system under study. The three-phase system is considered as balanced and loads are assumed as time invariant. The cost of the operation and maintenance of the capacitor placed in the system are assumed to be neglected. The largest capacitor size cannot be more than total reactive load at a particular bus [19].Mathematically, the objective function[20]of the problem is the cost which includes the cost of power loss and the capacitor placement which is to be minimized under certain constraints as;

### Minimize

Objective function:

$$COST = K_p P_{T, Loss} + \sum_{i=1}^n K_i^c Q_i^c \quad (1)$$

### Subject to

$$\text{Voltage limit: } V_{min,i} \leq V_i \leq V_{max,i} \quad (2)$$

$$\text{Capacitor size limit: } Q_i^c \leq \sum_{i=1}^n Q_{Li} \quad (3)$$

Here,  $n$  is the number of buses,  $Kp$  is the equivalent annual cost per unit of power loss in \$/kW/year,  $K_i^c$  is the annual capacitor installation cost \$/kVAr,  $V_i$  is the voltage magnitude of bus  $i$ ,  $V_{min,i}$  and  $V_{max,i}$  are minimum and maximum voltage limits of  $i^{\text{th}}$  bus respectively,  $Q_i^c$  is the reactive power compensated at bus  $i$  and  $Q_{Li}$  is the reactive load power at bus  $i$ .

### III. IDENTIFICATION OF OPTIMAL LOCATION

Optimal locations for capacitor placements are the selected buses that can be determined using Loss Sensitivity Factors. The estimation of these buses helps in reduction of the search space for the optimization procedure. A distribution line with an impedance  $R+jX$  and a load of  $P_{eff} + jQ_{eff}$  connected between 'p' and 'q' buses is given below Fig. 1.

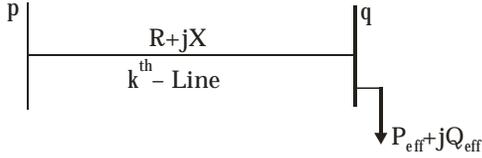


Fig. 1 Distribution Line with p and q Buses

Active power loss in the  $K^{\text{th}}$  line is given by  $[I_k^2] * R[k]$  which can be expressed as,

$$P_{lineloss}[q] = \frac{(P_{eff}^2[q] + Q_{eff}^2[q]R[k])}{(V[q]) * (V[q])} \quad (4)$$

Where,  $Peff[q]$  &  $Qeff[q]$  are the total effective active and reactive power respectively supplied beyond the node  $q$ .

Now, the Loss Sensitivity Factors [21] can be given by

$$\frac{\partial P_{lineloss}}{\partial Q_{eff}} = \frac{(2 * Q_{eff}[q] * R[k])}{(V[q]) * (V[q])} \quad (5)$$

Loss Sensitivity Factors ( $\partial P_{lineloss} / \partial Q_{eff}$ ) are calculated from load flow analysis of the given system and the values are arranged in descending order for all the lines of the system. The descending order will decide the sequence in which the buses are to be considered for compensation [22]. If the voltage at a bus in the sequence list is healthy (i.e.  $V[i] / 0.95 > 1$ ) such bus needs no compensation.

### IV. PLANT GROWTH SIMULATION ALGORITHM

Plant Growth Simulation Algorithm (PGSA) is a new type of intelligent optimization algorithm which is based on a computer system (namely L-systems) proposed by A. Lindenmayer and P. Prusinkiewicz *et al.* in the 1990s. L-system is used in the fractal domain and the computer graphics to simulate the plant growing and branching process. When plant outgrows, the main drive to promote its growth impetus comes from the sunlight, the auxin concentrations in plant are changed with photosynthesis, and the point which has received sufficient sunlight with more concentrations will grow prior. By using plant growth simulation algorithm to solve optimization problems is actually a simulation process of plant outgrowing to the whole space. The point which can outgrow a new branch in the plant is called growing point, the more auxin concentration of the growing point, the more growing opportunities it gets. The auxin concentration of plant is mainly decided by phototropic, it will be reassigned among each growing points if the environment location is changed. Tong Li *et al.* [23] analyzed the probability growth model of simulating the plants phototropic, and gives out auxin concentration calculating formulas of the stems and branches.

Assuming a plant grows a trunk  $M$  from its root and there are  $k$  initial growing points called nodes  $N_{M1}, N_{M2}, N_{M3}, \dots, N_{Mk}$  that have better environment than the root  $N_0$  on the trunk  $M$ .

The auxin concentration  $S_{M1}, S_{M2}, \dots, S_{Mk}$  of the nodes  $N_{M1}, N_{M2}, \dots, N_{Mk}$  can be calculated by

$$S_{Mi} = \frac{f(N_0) - f(N_{Mi})}{\sum_{i=1}^k [f(N_0) - f(N_{Mi})]} \quad (6)$$

The auxin concentration of the growing point can be more if the function of the nodes  $N_{M1}, N_{M2}, N_{M3}, \dots, N_{Mk}$  and  $N_0$  satisfy  $f(N_{Mi}) < f(N_0)$  for  $i=1, 2, 3, \dots, k$ . From (6), it can be calculated that summation of all concentration is equal to unity, which means that the auxin concentrations  $S_{M1}, S_{M2}, \dots, S_{Mk}$  of the corresponding nodes  $N_{M1}, N_{M2}, \dots, N_{Mk}$  form a state space shown in Fig 2.

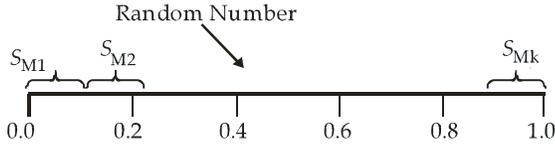


Fig. 2 Auxin Concentration State Space

Now Randomly generates a number within [0, 1] and drop into one of  $S_{M1}, S_{M2}, \dots, S_{Mk}$  as shown in Fig.2, the node corresponding to the selected concentration will be the next growing point. Repeat the above process until there is no new branch to grow and hence a complete plant will be formed.

Chung Wang *et al.* [24] suggested a model where the nodes on a plant can express the possible solutions,  $f(N)$  can express the objective function, the length of the trunk and the branch can express the search domain of possible solutions, the root of a plant can express the initial solution, the preferential growth node corresponds to the basic point of the next searching process. In this way, the growth process of plant phototropism can be applied to solve the problem of integer programming.

V. APPLICATION OF PROPOSED METHOD

The proposed method has been programmed using MATLAB. The effectiveness of the proposed method for loss reduction by capacitor placement is tested on 34-bus test radial distribution systems [25]. This system has a main feeder and four laterals (sub-feeders). The single line diagram is shown in Fig. 3. The rated line voltage of the system is 11 kV.

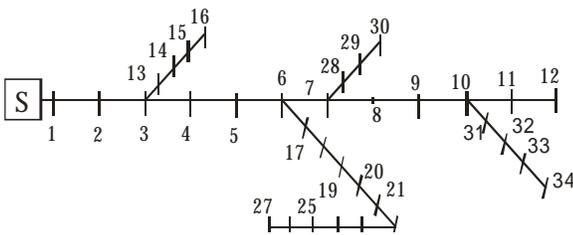


Fig.3 34-Bus Distribution Network

For this test feeder,  $K_p$  is selected to be 168\$/(kW-year) [19]. Only fixed capacitors with a life expectancy of 10 years (placement, maintenance and running costs are neglected) are used in the analysis and the marginal cost of capacitors ( $K_c^i$ ) [26] are used to compute the total annual cost. The method of sensitive analysis is used to select the candidate

installation locations of the capacitors to reduce the search space. The buses are ordered according to their sensitivity value ( $\partial P_{line\ loss} / \partial Q_{eff}$ ) (i.e., bus 19, 22, 20, 21, 23, 24, 25, 26, and 27). Now, the capacitors are placed on these selected buses and apply PGSA with all possible combinations of buses. The number of iterations tried from 2 to 100. All of the results converge to the same optimal solution with iteration greater than 8. The optimum locations with size of capacitors with the proposed method are compared with the Fuzzy reasoning [27] and are shown in Table I. The minimum voltage before capacitor placement is 0.9417 p.u at bus number 27 which has improved to 0.9498 p.u after capacitors placement

Table I  
Simulation Results of 34- Bus System and Its Comparison

Parameters	Uncompensated	Fuzzy reasoning [27]		Proposed PGSA	
Total losses (kW)	221.67	168.98		168.8	
Loss reduction (%)	...	23.76		23.850	
Optimal location and size in kVAr	...	24 17 7	1500 750 450	19 22 20	900 300 900
Annual Cost (\$ / year)	37,182	29010		28,797	
Net Saving (\$ / year)	...	8,172		8,384	

From the results shown in Table I, it is observed that the power loss and net annual savings obtained with proposed method are less than Fuzzy reasoning. Fig 4 shows the graph between number of buses used for capacitor placement and the losses in kW.

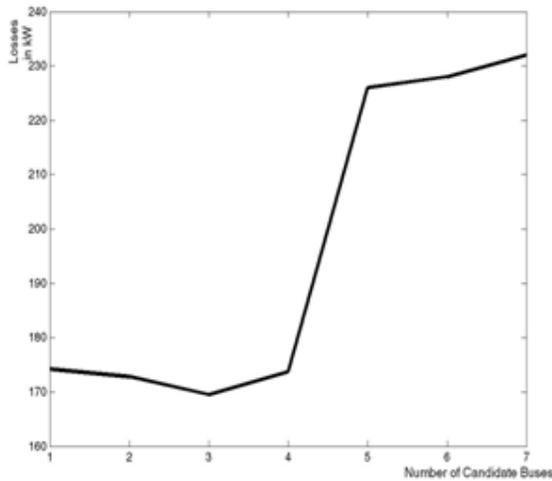


Fig.4 Losses Corresponds to Number of Candidate Buses

## VI. CONCLUSION

A bionic random search Plant Growth Simulation Algorithm (PGSA) for loss reduction in the distribution system has been proposed. The loss sensitivity factors are used to determine the candidate locations of the buses required for compensation. The PGSA is used to estimate the required level of shunt capacitive compensation at the optimal candidate locations to reduce the active power loss. The test results of 34 bus system have showed the best solutions than other approach available in the references. PGSA have many characteristics such as fewer parameters, easily coding and implement, fast calculating speed, no more restrictions or requirements in solving the objective function. In this paper capacitors at less number of locations with optimum size are placed which results in net annual saving. Also, practical values of capacitors are considered with a finite number of sizes rather than continuous capacitors size.

## VII. REFERENCES

- [1] Y. H. Song, G. S. Wang, A. T. Johns and P.Y. Wang, "Distribution network reconfiguration for loss reduction using Fuzzy controlled evolutionary programming," *IEEE Trans. Gener., Trans., Distri.*, Vol.144, No.4, July 1997.
- [2] H. D. Chiang, J. C. Wang, O. Cockings, and H. D. Shin, "Optimal capacitor placements in distributions systems: Part 1 and 2," *IEEE Trans. Power Del.*, Vol. 5, No. 2, pp. 634–649, Apr. 1990.
- [3] M. E. Baran and F. F. Wu, "Optimal Capacitor Placement on Radial Distribution Systems", *IEEE Trans. on Power Delivery*, Vol. 4, No. 1, January 1989.
- [4] M. M. A. Salama and A. Y. Chikhani, "A simplified network approach to the VAR control problem for radial distribution systems," *IEEE Trans. Power Delivery*, vol. 8, no. 3, pp. 1529–1535, Jul. 1993.
- [5] S. Civanlar and J. J. Grainger, "Var Control on Distribution Systems with Lateral Branches Using Shunt Capacitors and Voltage Regulators: Part 1. Part 11, Part III", *IEEE Trans. on Power Apparatus and systems*, vol. 104, pp. 3278-3297, Nov. 1985
- [6] J. J. Grainger, and S. H. Lee, "Optimum Size and Location of Shunt Capacitors for Reduction of Losses on Distribution Feeders", *IEEE Trans. on Power Apparatus and Systems*, vol. 100, pp. 1105-1 118, March 1981.
- [7] M. Chis, M. M. A. Salama, and S. Jayaram, "Capacitor placement in distribution systems using heuristic search strategies," *Proc. Inst. Elect.Eng. Gen. Transm. Dist.*, vol. 144, no. 3, pp. 225–230, 1997.
- [8] M. M. Hamada, M. A. A. Wahab, A. M. El-Sayed, H. A. Ramadan, "A proposed strategy for capacitor allocation in radial distribution feeders," in *Conf. 12th Middle East Power Systems Conf., MEPCON, Aswan, Egypt*, 12-15 March 2008
- [9] S.Sundhararajan and A. Pahwa, "Optimal selection of capacitors for radial distribution systems using a genetic algorithm," *IEEE Trans. Power Systems*, vol. 9, no.3, pp. 1499-1505, Aug. 1994.
- [10] Dong Zhang Zhengcai Fu and Liuchun Zhang, "Joint Optimization for Power Loss Reduction in Distribution Systems", *IEEE Trans. Power Syst.*, vol.23, no.1, Feb. 2008, pp. 161-169
- [11] S.Jalilzadeh, S. Galvani, H. Hosseinian, F.Razavi, "Voltage Profile Modification Using Genetic Algorithm In Distribution Systems," in *Proceedings of the World Congress on Engineering and Computer Science 2007 WCECS 2007*, October 24-26, 2007
- [12] T. Ananthapadmanabha, A. D. Kulkarni, A. S. Gopala Rao, and K. Raghavendra Rao, "Knowledge-based expert system for optimal reactive power control in distribution system," *Electrical Power & Energy Systems*, vol. 18, no. 1, pp. 27–31, 1996
- [13] Mekhamer, S.F., Khattab, H.M., Mahmoud, A.M.A., "Solution of the Capacitor allocation problem in distribution feeders considering load variation: A modified simulated annealing based approach" in *Proc. Int. Conf. power Systems Conference, 2006. (MEPCON 2006), 19-21 Dec. 2006*, pp. 302-309.
- [14] S. M. Kannan, A. Rathina Grace Monica, and S. Mary Raja Slochanal, "Fuzzy Logic Based Optimal Capacitor Placement on Radial Distribution Feeders," in *Proc. Int. Conf. Power System Technology and IEEE Power India Conference, 2008(POWERCON 2008)*, 12-15 Oct. 2008, pp. 1-6.
- [15] H Masoum, M.A.S., Jafarian, A., Ladjevardi, M., Fuchs, E.F., Grady, W.M., "Fuzzy approach for

- optimal placement and sizing of capacitor banks in the presence of harmonics ,” *IEEE Trans. Power on Delivery*, vol. 19, no.2, pp 822-829, Apr. 2004.
- [16] AlRashidi, M.R., El-Hawary, M.E., “A Survey of Particle Swarm Optimization Applications in Electric Power Systems ,” *IEEE Transactions on Evolutionary Computation*, vol. 13, no.4, pp. 913-918, Aug. 2009.
- [17] Etemadi, A.H., Fotuhi-Firuzabad, “ Distribution system reliability enhancement using optimal capacitor placement,” *Generation, Transmission & Distribution, IET*, vol. 2, no. 5, pp. 621-631, July 2008.
- [18] Chung-Fu Chang, “Reconfiguration and Capacitor Placement for Loss Reduction of Distribution Systems by Ant Colony Search Algorithm ,” *IEEE Trans. Power Syst.*, vol. 23, no. 4, pp. 1747 - 1755 ,Nov. 2008.
- [19] Y. Baghzouz and S. Ertem, “Shunt Capacitor Sizing for Radial Distribution Feeders with Distorted Substation Voltages,” *IEEE Trans Power Delivery*, Vol. 5, No. 2, pp.650–657, April 1990.
- [20] J. J. Grainger and S. H. Lee, “Capacity Release by shunt capacitor Placement on distribution Feeders,” *IEEE Trans. on Power Apparatus and Systems*, Vol. 101, No. 5, pp. 1236-1244, March 1982.
- [21] Prakash K. and Sydulu M, “Particle swarm optimization based capacitor placement on radial distribution systems,” *IEEE Power Engineering Society general meeting*, pp. 1-5, 2007.
- [22] Su C. T and Tsai C. C, “A new fuzzy reasoning approach to optimum capacitor allocation for primary distribution systems,” *Proc IEEE on Industrial Technology Conf*, 1996; pp. 237–41.
- [23] Tong Li, Chunfeng Wang and Wenbo Wang *et al.*, “A global optimization bionics algorithm for solving integer programming- plant growth simulation algorithm,” *Systems Engineering-Theory and Practice*, vol.25, no.1, pp.76-85,2005
- [24] Chun Wang and Hao Zhong Cheng, “Optimization of network reconfiguration in large distribution systems using plant growth simulation algorithm,” *IEEE Trans. on Power Systems*, Vol.23, No.1, pp. 119-126, Feb. 2008.
- [25] M. Chis, M. M. A. Salama, and S. Jayaram, “Capacitor placement in distribution systems using heuristic search strategies,” *Proc. Inst. Elect. Eng.*, Vol. 144, No. 2, pp. 225–230, May 1997.
- [26] S. F. Mekhamer, “New heuristic strategies for reactive power compensation of radial distribution feeders,” *IEEE Trans Power Delivery*, Vol. 17, No. 4, pp.1128–1135, October 2002.
- [27] H. N. Ng, M. M. A. Salama and A. Y. Chikhani , “Capacitor Allocation by Approximate Reasoning: Fuzzy Capacitor Placement,” *IEEE Trans. Power Delivery*, Vol. 15, No.1, pp. 393-398, Jan. 2000.