

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

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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^{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.

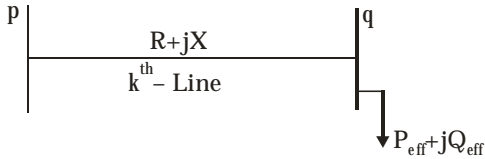


Fig. 1 Distribution Line with p and q Buses

Active power loss in the K^{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, $P_{eff}[q]$ & $Q_{eff}[q]$ 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.

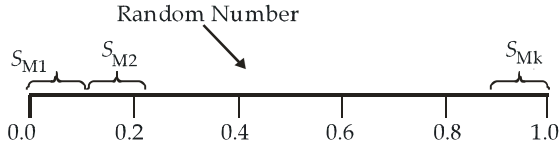


Fig. 2 Auxin Concentration State Space

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.

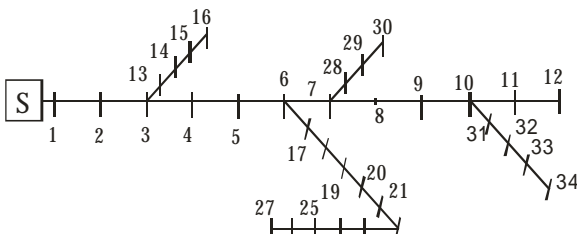


Fig.3 34-Bus Distribution Network

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.

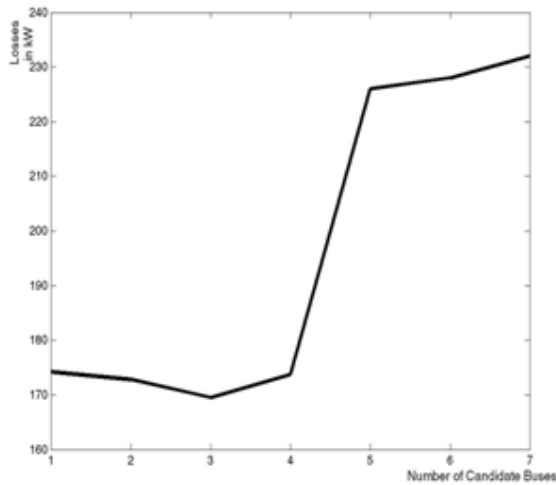


Fig.4 Losses Corresponds to Number of Candidate Buses

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

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