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Placement Of Distributed Generation In A Radial Distribution System Using Loss Sensitivity Factor And Cuckoo Search Algorithm

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ABSTRACT

In electrical distribution system active power losscan beminimized by several of methods to raise the overall efficiency of power system. The one method which has been proposed in this article issuitably placing and sizing of Distributed Generation in radial distribution system. The method comprises of two stages. In first stage loss sensitivity factor is used to find the weak bus for Distributed Generation placement and in second stage Cuckoo Search Algorithm is used for loss minimization and voltage profile improvement. The proposed method is tested on 33-bus and 69-bus system and results are given below.

Keywords: Cuckoo search algorithm, Loss sensitivity factor,Radial distribution system, Distributed Generation.

1.INTRODUCTION

Electricity has now become like a life line. To do any small or large work electricity has become one of the important needs. As the population is increasing the need and use of electricity is also increasing and thus increasing the load demand. Due to high load demand, the system losses are increasing and it is affecting the voltage profile and voltage profile is decreasing. One method to minimize this power loss and to improve voltage profile is by placing Distributed generation. Distributed generation refers to small scale power generation having ratings between 1kW to 50 MW. These small power generators produce electricity at a site close to consumers. The main sources of electricity on which a huge population depends is thermal, nuclear and hydro power plants. But due to large dependencies and consumption of coal, petroleum and other fossil fuels has created scarcity of these resources. The other renewable sources like wind and solar is becoming an alternative for those non-renewable sources. Day to day they are becoming more economical and technical. A lot of research work has already been done in this field of Distributed Generation and a lot of research work is going on.Like Genetic algorithm, tabu search, analytical based methods [1], heuristic algorithms [2] and metaheuristic algorithms developed based on the swarm intelligence in nature like PSO, AFSA [3] and SFLA [4]. Willis [5] developed ''2/3 rule''which is related to optimal capacitor location, for finding an ideal bus for DG location. Due to these assumptions its applicability is limited to radial distribution systems and for that reason it is only suitable for one DG planning. Wang and Nehrir employed an analytical method to find the optimal DG location in distribution systems with different load topologies while the main objective of that was to minimization of real power losses. In the research, the DG units were assumed to have unit power factor, and the overhead lines with neglected shunt capacitance are studied [6]. Popovic et al. [7] applied sensitive analysis that was based on the power flow equations for locating and sizing of DGs. In all of the buses two indices were used for suitable locating the DGs. Iyer et al. [8] employed the primal–dual IP method for finding optimal DG location by using both line loss reduction and voltage profile improvement indices. However, the method was based on initial location of DGs at all of the buses in order to determine DGs proper placements. For large scale systems this method may not be realistic. Rau and Yih-Heui [9] used the generalized reduced gradient method for DG sizing problem. They have used this method for minimizing the system losses. In this proposed method, only the power flow constrains taken, whereas the inequality constraints and the boundary conditions were studied. Teng et al. [10] employed a value-based approach for locating the DGs'. The GA method was used in maximizing DG's benefit cost ratio index which its boundary is determined with voltage drop and feeder transfer capacity. Falcao and Borges[11] utilized the metaheuristic method for solution of single andmultiple DG sizing and locating problems. They used the GA method to maximize a DG benefit to total cost ratio index. Pluymers et al. [12] employed the GA method for optimum solution of DG's related problems. They used a photo voltaicmodel for DGmodeling. The objective function that was taken into consideration was ratio index from maximizing benefit of DG to total cost. Moradi and Abedini [13] utilized the hybrid technique in solving multiple DG sizing and locating, to find optimal DG location through combined losses reduction, voltage profile improvement and increasing the voltage stability within the framework of system and security constraints in network systems. In this method they have used both GA and PSO, the GA for locating and particle swarm optimization (PSO) for sizing the DGs [14].

2. PROBLEM FORMULATION

Here the main objective is to minimize the total power loss and to improve voltage profile. To solve the DG placement and sizing problem the following objective function has been taken.

$$\text{Minimize}\, S_{LOSS} = \sum_{i=1}^{n} (P_{LOSS} + Q_{LOSS}) \qquad (1)$$

Voltage magnitude at each bus must be maintained within its limit and can be expressed as

$$V_{min} \le |Vi| \le V_{max} \qquad (2)$$

Where $|V_i|$ is the voltage magnitude at bus i and V_{min} and V_{max} are the minimum and maximum voltage limits respectively.For the calculation of power flows the following sets of simplified recursive equations which are derived from single line diagram are shown in fig 1.

$$P_{i+1} = P_i - P_{Li+1} - R_{i,i+1}.\frac{(P_i^2 + Q_i^2)}{|V_i|^2} \quad (3)$$

$$Q_{i+1} = Q_i - Q_{i+1} - X_{i+1}.\frac{(P_i^2 + Q_i^2)}{|V_i|^2} \quad (4)$$

$$|V_{i+1}|^2 = |V_i|^2 - 2(R_{i,i+1}.P_i + X_{i,i+1}.Q_i) + (R_{i,i+1}^2 + Q_{i,i+1}^2).\frac{(P_i^2 + Q_i^2)}{|V_i|^2} \quad (5)$$

Where P_i and Q_i are the real and reactive power flowing out of busi ,P_{Li} and Q_{Li} are the real and reactive load powers at bus i. The resistance and reactance of the line section between bus i and i+1 are denoted by $R_{i,i+1}$ and $X_{i,i+1}$.The power loss of the line section connecting the buses i and i+1 may be calculated as:

$$P_{LOSS}(i,i+1) = R_{i,i+1}.\frac{(P_i^2 + Q_i^2)}{|V_i|^2} \quad (6)$$

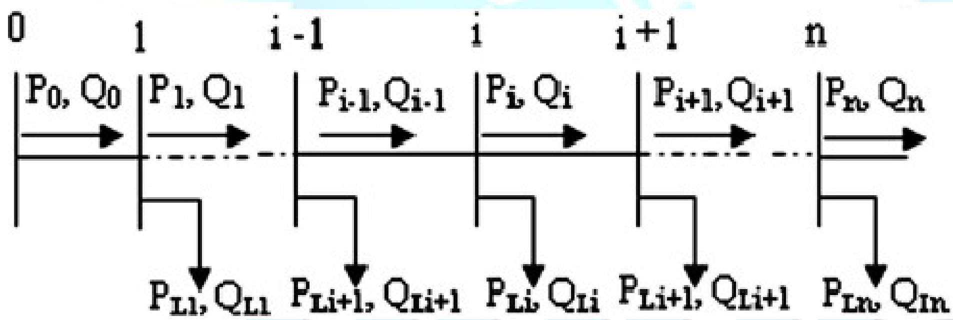


Fig1.Singleline diagram ofmain feeder.

The total power loss of the feeder $P_{T,LOSS}$can be computed by summing up the losses of all the line sections of the feeder, and given as

$$P_{T,LOSS} = \sum_{i=1}^{n} Ploss(i, i+1) \quad (7)$$

2.1 Constraints

Each DG size minimizing the objective function, must verify the equality and inequality constraints. Two inequality constraints are considered here for DG placement that must be satisfied are as such:

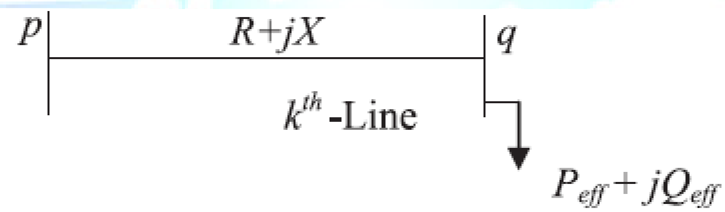
(I) $V_{min} \leq |Vi| \leq V_{max}$ i.e 0.95 P.U≤ |Vi| ≤ 1.00 P.U (8)

(ii) $P_{DG\,min} \leq P_{DGi} \leq P_{DGmax}$ i.e 0.1 MW≤ $|P_{DGi}|$ ≤ 3.7 MW. (9)

P_{DG} is the minimum and maximum real power generation from DG Capacity in MW.

2.2 Sensitivity Analysis and Loss Sensitivity Factors

By using loss sensitivity factors the candidate nodes for the DG placement is determined. By estimation of these candidate nodes it helps in the reduction of search space for optimization problem.Considering a distribution linewith an impedance R+jX and a load P_{eff} and Q_{eff} connected between buses p and qis given by.



Active power loss can be given by in (3) is rewritten for k^{th} line between buses p and q as

$$P_{lineloss}[q] = \frac{(P_{eff}^2[q]+Q_{eff}^2[q])R[k]}{(V[q])^2} \quad (11)$$

Similarly the reactive power loss in the k^{th} line is given by

$$Q_{Lineloss}[q\,] = \frac{(P_{eff}^2[q]+Q_{eff}^2[q])X[k]}{(V[q])^2} \quad (12)$$

Where $P_{eff}[q]$ = Total effective active power supplied beyond the node 'q'.$Q_{eff}[q]$= Total effective reactive power supplied beyond the node 'q'.

Both the loss sensitivity factor can be given as:

$$\frac{\partial Plineloss}{\partial Qeff} = 2 * \frac{Q_{eff}[q] * R[k]}{V[q]^2} \quad (13)$$

$$\frac{\partial Qlineloss}{\partial Qeff} = 2 * \frac{Q_{eff}[q] * X[k]}{V[q]^2} \quad (14)$$

2.3.Candidate node selection using loss sensitivity factors

The Loss Sensitivity Factors ($\frac{\partial Plineloss}{\partial Qeff}$) are calculated from the base case load flows and the values are arranged in descending order for all the lines of the given system. A vector bus position 'bpos[i]' is used to store the respective 'end' buses of the lines arranged in descending order of the values ($\frac{\partial Plineloss}{\partial Qeff}$).The descending order of ($\frac{\partial Plineloss}{\partial Qeff}$) elements of ''bpos[i]' vector will decide the sequence in which the buses are to be considered for compensation. This sequence is purely governed by the ($\frac{\partial Plineloss}{\partial Qeff}$) and hence the proposed 'Loss Sensitive Coefficient' factors become very powerful and useful in DG allocation orPlacement.At these buses of 'bpos[i]' vector, normalized voltage magnitudes are calculated by considering the base case voltage magnitudes given by (norm[i] = V[i]/0.95). Now for the buses whose norm[i] value is less than 1.01 are considered as the candidate buses requiring the DG Placement. These candidate buses are stored in 'rank bus' vector. It is worth note that the 'Loss Sensitivity factors' decide the sequence in which buses are to be considered for compensation placement and the 'norm[i]' decides whether the buses needs Q-Compensation or not. If the voltage at a bus in the sequence list is healthy (i.e., norm[i] > 1.01) suchbus needs no compensation and that bus will not be listed in the'rank bus' vector. The 'rank bus' vector offers the information aboutthe possible potential or candidate buses for DG placement.

3.CUCKOO SEARCH ALGORITHM

The Cuckoo search algorithm is a recently developed optimization process by Xin-she yang and suash 2009.The basic concept of algorithm is inspired by a bird family called cuckoo because of their unique life style and aggressive reproduction techniques. They lay their eggs in the nests of other birds and also remove the existing eggs which increase the hatching probability of their eggs. Also, some of the host birds are able to combat this parasites behavior of cuckoos and either they throw out the discovered alien eggs or they build their new nests in a new locations. Herepopulations of nests or eggs are considered in this algorithm. The following representations are used where each egg in a nest represents a solution and a Cuckoo egg represents a new solution. If the egg of the cuckoo is very similar to the host's egg, then the egg of the cuckoo bird is less likely to be discovered by the host bird, so the fitness should be related to the difference in solutions. The aim of this algorithm is that not so good solution should be replaced by a new and good one.

The three idealized rule of Cuckoo search algorithm are:

1. Each Cuckoo lays one egg at a time and dumps it in a randomly chosen nest.

2. The best nests with high quality of eggs are carried over to the next generations.

3. The number of available host nest is constant, and the egg of Cuckoo is discovered by the host bird with a probability of pa in the range of [0, 1]. The later assumption can be approximated by the fraction pa of the n nests which is replaced by new ones (with new random solutions).

4. PROPOSED OPTIMAL DISTRIBUTED GENERATION PLACEMENT METHODOLOGY

Here in this proposed method the Cuckoo Search algorithm is applied as an optimization technique to determine the optimal size of the distributed generation at the buses.Power flow is used for the computation of power loss.The procedures for implementation of the proposed optimal DG placement method has been described in two stages are as follows:

Determination of candidate location

Step1:Input all the parameters like line data and load data.
Step2:Run the load flow as explained above by using set of simplified recursive equation.
Step3:Calculate the loss sensitivity factor.
Step4:Select the buses whose norm[i] value is less than 1.01 as candidate location.

Optimization using CUCKOO SEARCH Algorithm.

Step1:Perform the load flow to find initial losseswithout any DG placement. The losses value will be the first fitness value FV_1 for the algorithm;
Step2:Set all the parameters of Cuckoo search such as: number of host nests (n = 25), maximum number of iterations (niter = 70), probability (pa = 0.25) for the worst nest.
Step3:Randomly initialize the solutions Nest (i,:)=Lb+(Ub-Lb).*rand(size(Lb)) Get the current best for objective function.
Step4:Start iterations
Step5: Again perform the load flow to find the power loss with DG placement. The losses value will be the second fitness value FV_2 for the algorithm.
Step6: Compare both the values and find out total power loss reduction.
Step7: Generate new solutions (but the current best should be kept).
s=s + step size.*randn (size(s)).
Step8: Discovery for the new nest and the process of randomization are;
K=rand (size(nest))>pa
step size=rand*(nest(rand(n),:)-nest(rand(n),:))
new nest=nest + stepsize.*K
Step9: Evaluate this set of solutions
Step10:Find the best objective function so far.
Step11:Increment iteration count and if the iteration count is not reached go to step 8.
Step12:Repeat the procedure till end of iterations and get the value of the best objective function.

5.RESULT:

Loss sensitivity factor is used to calculate the candidate location for the DG placement and Cuckoo search algorithm is used to find the optimal DG size.Population size n=25 and Discovery rate of alien eggs/solutions Pa=0.25

5.1. Results of 33-bus system

The proposed algorithm is applied to 33-bus system[13]. Optimal DG locations are identifiedbased on the Loss sensitivity factor values. For this 33-bus system, one optimal location is identified. DG size in that optimal location, total real power losses before and aftercompensation,voltage profile before and after compensation are shown below in Table1.

BUS NO;	6
DG SIZE in (kW)	1000
TOTAL REAL POWER LOSS in(kW) before compensation.	201.8588
TOTAL REAL POWER LOSS in (kW) after compensation.	99.3699
TOTAL REACTIVE POWER LOSS in(KVAr) before compensation.	134.2563
TOTAL REACTIVE POWER LOSS in(KVAr)after compensation	48.1836
VOLTAGE IN P.U at bus number 6 before compensation.	0.9499
VOLTAGE IN P.U at bus number 6 after compensation	0.9936
REAL POWER LOSS REDUCTION	102.4889
REAL POWER LOSS REDUCTION %	50.7725%

5.2. Results of 69-bus system

The proposed algorithm is applied to 69-bus system [14]. Optimal DG location is identified based on the Loss sensitivity factor values. For this 69-bus system, one optimal location isidentified. DG sizes in that optimal location, total real power losses before and aftercompensation,voltage profile before and after compensation, are shown below in Table-2.

BUS NO;	61
DG SIZE in (kW)	2000
TOTAL REAL POWER LOSS in(kW) before compensation	224.5407
TOTAL REAL POWER LOSS in (kW) after	156.8782

compensation	
TOTAL REACTIVE POWER LOSS in(KVAr) before compensation.	101.9661
TOTAL REACTIVE POWER LOSS in(KVAr) after compensation	73.1398
VOLTAGE IN P.U at bus number 61 before compensation	0.9133
VOLTAGE IN P.U at bus number 61 after compensation	0.9332
REAL POWER LOSS REDUCTION	67.6625
REAL POWER LOSS REDUCTION %	30.1337%

6.CONCLUSION

In this paper a two- stage method Loss sensitivity factor and Cuckoo search algorithm has been successfully applied for DG placement. By the installation of distributed generation at the optimal position there is a significant decrease in power lossand increase in voltage profile.So the combination of both Loss sensitivity factor and Cuckoo algorithm yields good results.

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