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Optimal Allocation and Sizing of multiple Distributed Generation in distribution network by Ant Colony Search Algorithm

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Abstract—The Aim of this paper is to reduce the losses and improving voltages by connecting number of Distributed Generation (DG) at optimal places. Ant Colony Search Algorithm (ACSA) is used for optimal allocation and sizing of DG in distribution network. ACSA is a software program which is implemented in MATLAB .In this paper the output results shows that as the number of DG's increases up to 5 the voltages of all the buses increases and losses decreases and more than 5 DG's losses are increased. The optimal allocation of DG's is implemented on IEEE 15 bus system. The improper allocation causes to over currents, over voltages and harmonics in the distribution network.

Keywords-Distributed Generation (DG); Allocation; Losses; Ant Colony Search Algorithm (ACSA).

I. INTRODUCTION

In recent years, the power demand increasing due to the rise in population. In rural areas the power supply from sub-station to the load is a radial network. In this radial network feeder is fed from one end and loads are connected at the other end .Therefore voltage levels are decreased as we go away from sub-station. The distribution network requires satisfying the inequality constraints (voltage, real power, reactive power). The DG's are used to satisfy the inequality constraints in the distribution network [2].

The distributed generators are small capacity generators connected nearer to the loads. The distributed generation requires to be connected at a optimal place in distribution network to satisfy the inequality constraints. For optimal location of DG's it requires an optimization technique. In this paper ACSA (Ant Colony Search Algorithm) is used as optimization technique to connect DG's in optimal places. The main advantages of connection of DG in distribution network are

- Improving the voltage levels of all buses in distribution network.
- Reducing the losses in distribution network.
- Improving the reliability of the distribution network.

II. IDEA OF ANT COLONY SEARCH ALGORITHM

The optimization technique ACSA comes from the natural behaviour of ant colony. Ant colony explains how the ants find the shortest path without having any visual clues. During the process of searching food the ants release a pheromone in the paths while they are walking in different paths from nest to food source. The later ants follow the same paths by smelling the pheromone. After a larger number of ants walk on the paths, a path with high concentration of pheromone will appear, and then the path is the shortest path [1].

A. *Mathematical formulae for ACSA :*

ACSA is designed mainly in three steps

- Pheromone initialization
- Update pheromone
- Building tour

1) *Pheromone initialization*

The initial pheromone of each path is considered as $T_{ij}(0)$, Where $T_{ij}(0)$ is pheromone concentration between the cities i and j is zero.

2) *Pheromone path building:*

There is formation of pheromone path along all the cities, Let K[th] ant is placed in i[th] dot. In this case the probability of choosing j dot is as a target, in the other words, choosing the replacement path ij is obtained by the following equation.

$$P_{ij}(k)(t) = \begin{cases} \dfrac{\tau_{ij}^{\alpha}(t).\eta_{ij}^{\beta}}{\sum_{s} \tau_{ij}^{\alpha}(t).\eta_{is}^{\beta}} & Tabu\ (k) \in j, s \\ 0 & Otherwise \end{cases} \quad ...(1)$$

In this equation τij(t) is the left pheromone rate in the replacement ij path in time t. ηij is the rate that shows the replacement of pheromone path ij. For placement problem DG, the rate of ηij is obtained by following equation

$$n_{ij} = \frac{1}{d_{ij}} \quad ....(2)$$

d_{ij} is the observed losses with the link between (j, i) dots and path ij.

3) *Update pheromone:*

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The total pheromone of each path is updated by the following equation

$$\tau_{ij}^{k+1}(t) = (1-\rho)\times\tau_{ij}^{k}(t) + \text{delta}\ \tau_{ij} \quad ....(3)$$

Where ρ is the pheromone evaporation constant. The value of ρ is positive number between 0 and 1.

III. Problem Formulation

1) Problem formation for improving voltages:

The equivalent circuit of three nodes distribution network without DG connection is shown in figure 1.

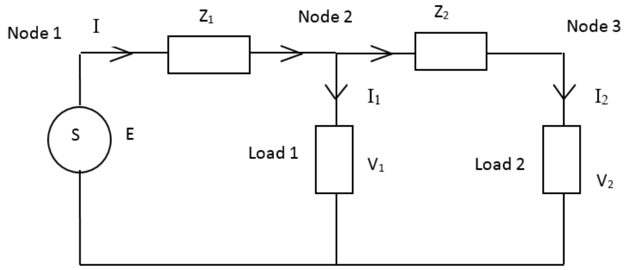

Figure.1: Three nodes distribution network without DG

S = Substation

E = Substation Voltage

I = Substation supply Current of Radial Feeder.

I_1 = Load 1 Current

I_2 = Load 2 Current

V_1 = Load 1 Voltage

V_2 = Load 2 Voltage

Z_1 = Line Impedance between Node 1 and 2

Z_2 = Line Impedance between Node 2 and 3

$$V_1 = E - IZ_1 \quad ....(4)$$

$$V_2 = E - (IZ_1 + I_2Z_2) \quad ....(5)$$

$$V_i = E - \sum_{i=1}^{n} I_iZ_i \quad ....(6)$$

When the loads are connected away from substation voltages are decrease at the loads.

The equivalent circuit of three nodes distribution network with DG connection is shown in figure 2.

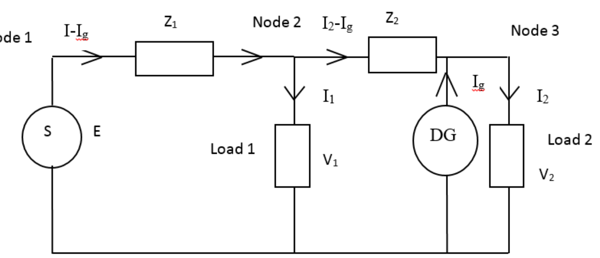

Figure 2 : Three nodes distribution network with DG

I_g = DG current Injecting into Distribution Network

$$V_1 = E - (I - I_g)Z_1 \quad ....(7)$$

$$V_2 = E - ((I - I_g)Z_1 + (I_2 - I_g)Z_2) \quad ....(8)$$

$$V_i = E - \sum_{i=1}^{n}(I_i - I_g)Z_i \quad ....(9)$$

2) Problem formulation for loss reduction:

From figure (1) the real power losses in distribution network

$$P = I^2R_1 + I_2^2R_2 \quad ....(10)$$

$$P_{total} = \sum_{i=1}^{n} I_i^2R_i \quad ....(11)$$

From figure (2) the real power losses in distribution network after DG connection.

$$P = (I - I_g)^2 R_1 + (I_2 - I_g)^2 R_2 \quad ....(12)$$

$$P_{total} = \sum_{i=1}^{n}(I_i - I_g)^2 R_i \quad ....(13)$$

The power losses after DG connection are less when compared to without DG connection to distribution network.

The inequality constraints of distribution networks are voltage limits, real and reactive power limits.

$$V_{min} < V_i < V_{max}$$

Where i is the bus number of distribution network

$$P_{min} < P_i < P_{max}$$

$$Q_{min} < Q_i < Q_{max}$$

The KVA outputs of DG's should satisfy the inequality constraints of network.

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IV. LOAD FLOW SOLUTION

The common Gauss-siedel and Newton-Raphson methods can not be used for distribution system as R/X ratio is high. The approach in this paper is based on topology based and is used for evaluating equivalent load at every node. This eliminates the complex process of identifying nodes connected beyond a particular node. The two developed matrices, 'bus injection to node power matrix and line loss to node power matrix' are very easy to form. In this method convergence is always guaranteed [3]-[7].

A. Convergence Condition

Repetition of ants' algorithm will finish when the convergence requirement satisfies. The convergence condition for this algorithm can be considered as density of paths pheromone or the numbers of passes on the paths. According to the mentioned explanations, total flow chart of ants' algorithm to solve the DG placement problem is given in fig.3

V. FLOW CHART OF ACSA

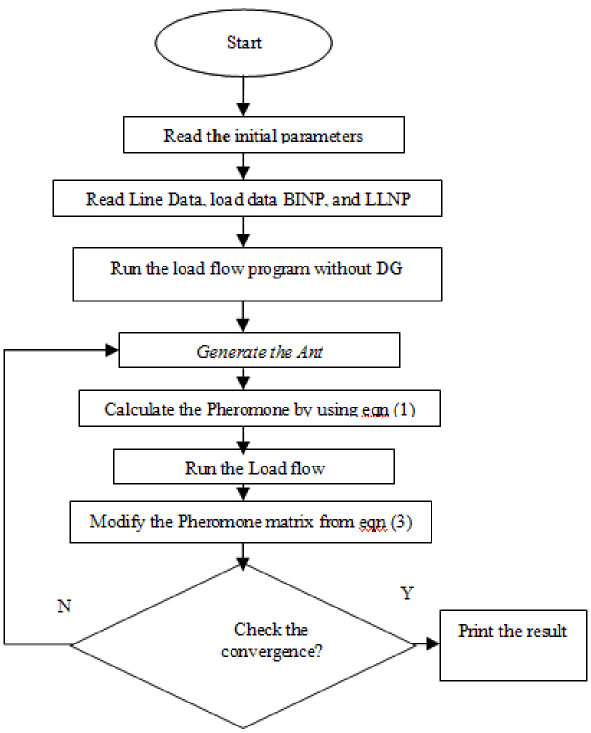

Figure.3 Flow chart of Ant Colony Search Algorithm

VI. OUTPUT RESULTS AND DISCUSSION

The output results of proposed algorithm are obtained from MATLAB program. The IEEE-15 bus distribution test system is shown in fig (4). The output results of per unit minimum, maximum voltages and per unit losses using ant colony is shown in table (I). By applying ACSA method, voltages at each bus with different number of DG's shown in fig.(5).

Fig.(6) shows that the real power losses of distribution network with different number of DG's. The fig.(7) show that the percentage real power losses decrease up to increase 5 number of DG's and losses increase more than 5 DG's.

Table (2) shows the per unit voltages at each bus for different number of DG's.

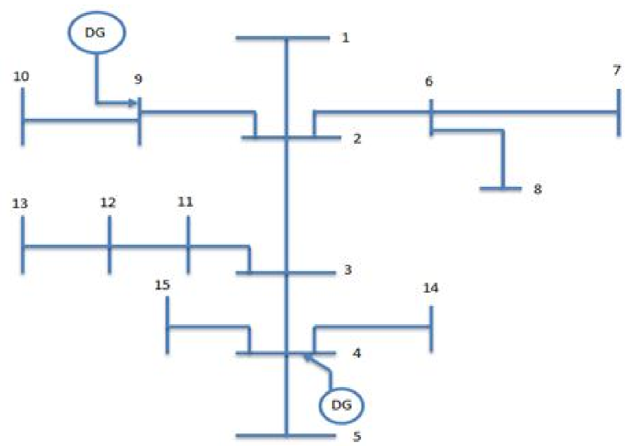

Figure.4 Distribution Network of 15 Bus

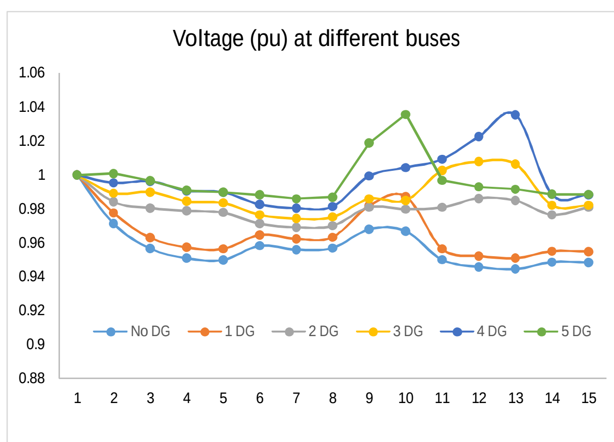

Figure.5 Voltage (pu) at different Buses

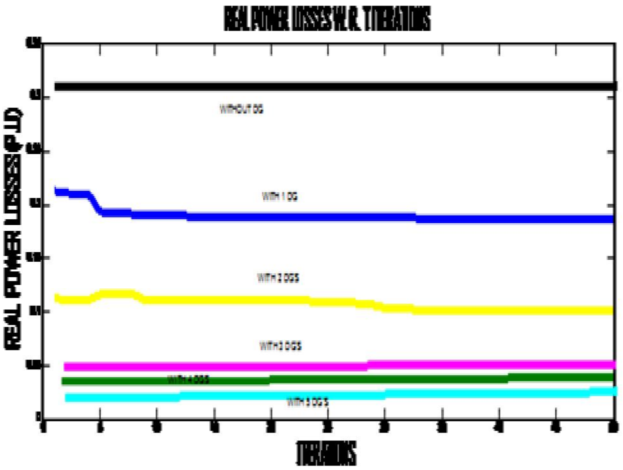

Figure.6 Real power losses with respect to iterations

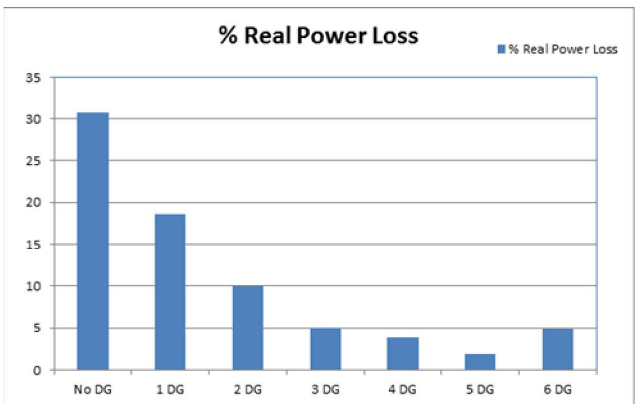

Figure.7 Percentage Real Power Loss at different DG's

Table 1: Comparison of DG's

	With out DG	1 DG	2 DG'S	3 DG'S	4 DG'S	5 DG'S	6 DG'S
Real Power Loss(p.u)	0.308	0.186	0.101	0.050	0.038	0.019	0.049
Reactive Power losses (p.u)	0.286	0.170	0.087	0.043	0.028	0.013	0.039
Min. Voltage (p.u)	0.944	0.950	0.969	0.974	0.98	0.986	0.99
Max. Voltage (p.u)	1.00	1.00	1.00	1.00	1.035	1.035	1.08

The location and sizing of 5 DG's output results.

Generator 1 connected at Bus no: 8, Size = 353.046027 KVA

Generator 2 connected at Bus no: 4, Size = 356.555199 KVA

Generator 3 connected at Bus no: 3, Size = 354.568848 KVA

Generator 4 connected at Bus no: 3, Size = 353.631645 KVA

Generator 5 connected at Bus no: 3, Size = 354.665793 KVA

Table 2: Per Unit voltages at different DG's

	No DG	1 DG	2 DG	3 DG	4 DG	5 DG	6 DG
Bus No	Voltage p.u						
1	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
2	0.971291	0.977579	0.984169	0.989262	0.995352	1.000839	1.005401
3	0.956671	0.963051	0.980554	0.989999	0.996295	0.996571	1.014972
4	0.950902	0.957316	0.978759	0.984426	0.990756	0.990870	1.009538
5	0.949915	0.956336	0.977800	0.983473	0.989809	0.989923	1.008609
6	0.958241	0.964615	0.971295	0.976456	0.982626	0.988186	1.002012
7	0.956018	0.962407	0.969101	0.974274	0.980459	0.986030	0.999887
8	0.956964	0.963346	0.970035	0.975202	0.981381	0.986948	1.005238
9	0.967979	0.981951	0.980900	0.986010	0.999380	1.018945	1.002202
10	0.966906	0.987293	0.979841	0.984957	1.004403	1.035742	1.001165
11	0.949955	0.956380	0.980892	1.002773	1.009264	0.996837	1.038904
12	0.945832	0.952285	0.986228	1.007765	1.022634	0.992909	1.067881
13	0.944520	0.950982	0.984970	1.006534	1.035556	0.991660	1.087014
14	0.948605	0.955035	0.976528	0.982208	0.988552	0.988666	1.007376
15	0.948437	0.954868	0.980946	0.982046	0.988391	0.988505	1.007217

VII. Conclusions

- By observing the graphs and tables the following results obtained:
- The voltages at each increase with increase the number of buses.
- The power losses are decrease with increase the number of buses.
- The maximum number of buses in IEEE-15 bus system is 5 because more than that loss are increasing and voltages exceed the inequality constraints limits.

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