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OPTIMAL PLACEMENT OF DISTRIBUTED GENERATION IN RADIAL DISTRIBUTION SYSTEM USING ANT COLONY SEARCH ALGORITHM WITH AND WITHOUT CONTINGENCY

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Abstract: An Ant Colony Search technique is used to solve the problem of optimal distributed generation (DG) allocation and sizing in radial distribution networks (ACSA). The objective is to determine the best size and position of distribution generators (DGs) for various IEEE radial distribution systems, such as 15-bus, 33-bus, and so on, while also noting the required number of DGs. Because there are various sources of DG, the suggested ACS method optimises both size and location. The objective is to keep the uniform voltage profile close to unity and hence minimise line losses in the radial distribution system. The problem's numerous practical restrictions are considered.

Index Terms - **Distributed Generation (DG), Distribution Network, Allocation, Losses, Ant Colony Search Algorithm (ACSA), Voltage Profile, Loss Reduction.**

I. INTRODUCTION

The generated power from large generating stations, which are typically located far from populated areas, must be transmitted over hundreds of kilometres via UHV (1200kV) and EHT transmission lines to substations with maximum transmission capacities ranging from 250MVA to 9000MVA at various voltage levels [1]. Power will be supplied to consumers at voltage levels ranging from 11kV to 33kV from EHT substations. Transmission and distribution losses are higher when power is delivered from larger power plants to consumers across longer distances. For the fiscal year 2018-19, transmission and distribution losses in India were estimated to be around 20.66 percent [2].

The distribution system will provide power at the proper voltage rating to each customer's service entrance. When compared to transmission levels, the X/R ratio for distribution levels is low, resulting in considerable power losses and a voltage magnitude drop along radial distribution lines. The distributed system's power losses are estimated to be around 13% of total power generation [3]. These massive power losses will impair the distribution system's overall efficiency and have a direct influence on distribution utilities' financial performance. Traditionally, these distribution power losses have been reduced by properly dispatching reactive power control devices, which can be accomplished by deploying reactive power control devices.

Because of their overall favourable impacts on power networks, the installation of Distributed Generation (DG) units is becoming more common in distribution systems. The fundamental reason for this was that the cost savings from larger power plants were offset by the increased expenses of transmitting and distributing electricity to consumers. The primary advantage of DG is that it promises significant cost savings in transmission and distribution. Reduced power losses, improved voltage profiles, reduced emission impacts, and improved power quality is just a few of the key benefits of integrated DGs.

There are several methods for determining the best position for DGs in distribution networks. Artificial Intelligence (AI), evolutionary computation, and optimization approaches are currently among the most commonly utilised techniques to handle these difficulties. Furthermore, because installing DG units is not simple, the placement and sizing of DG units should be carefully considered.

II. OBJECTIVE

The main goal of this paper is to solve the optimal DG placement and sizing problem in distribution networks. This problem of optimal allocation and sizing of distributed generation (DG) in radial distribution networks is treated by using an Ant Colony Search algorithm (ACSA). This algorithm is inspired from the natural behavior of the ant colonies on how they find the food source and bring them back to their nest by building the unique trail formation.

The objective is to determine the optimal size and location of distribution generators (DG's) for various IEEE radial distribution systems such as 15-bus, 33-bus, 57-bus, 85-bus, etc duly mentioning the required number of distribution generators. The objective function considered in this paper is to maintain the uniform voltage profile near to unity and thereby reduce the line losses in radial distribution system.

III. DISTRIBUTION GENERATION

The term Distribution Generation is used to refer to generating units that are connected to the distribution system instead of connecting to the transmission system. It is sometimes referred as embedded generation because they are embedded to distribution system. The advances in technology have created a new trend for the growth of Distribution Generation (DG). The renewed popularity of DG is creating new opportunities for increasing the diversity and improve the efficiency of electrical power system.

A. Distribution Generation - Definition

There is neither a standard definition nor a standard name for it has been agreed upon. Nevertheless, various definitions and names have been used. Some researchers define DG by rating DG units, whereas others define DG in terms of the technology used. DG also appears under different names, depending on the country.

i. DPCA (Distributed Power Coalition of America):

Distributed power generation is any small-scale power generation technology that provides electric power at a site closer to customers than central station generation. A distributed power unit can be connected directly to the consumer or to a utility's transmission or distribution system.

ii. CIGRE (International Conference on High Voltage Electric Systems):

Distributed generation is - Not centrally planned - Today not centrally dispatched - Usually connected to the distribution network - Smaller than 50 or 100 MW.

iii. IEA (International Energy Agency):

Distributed generation is generating plant serving a customer on-site, or providing support to a distribution network, and connected to the grid at distribution level voltages.

B. Distribution Generation Technology

There are various Distributed Generation technologies are available and tremendous research work is going in this area. Some of these technologies have been in use for a long time while others are newly emerging. Nonetheless, the features that all DG technologies have in common are to increase efficiency and decrease costs related to installation, running and maintenance. DG technologies are loosely categorized into two types: renewable technologies (e.g., photovoltaic and wind turbine) and non-renewable technologies (e.g., mini and micro- turbines, combustion turbines and fuel cells). Some of the popular Distributed Generation technologies are listed below [6]:

- Fuel cells
- Micro-Turbines
- Photovoltaic (PV) system
- Reciprocating Diesel or Natural Gas Engines
- Combustion Gas Turbines
- Wind Turbines

One of the reasons behind that is the awareness of the harmful gas emissions associated with the generation of electrical energy. This motivates the utilization of more environmentally responsible alternatives renewable energy resources. In addition, the growing open electric power market inspires more penetration of DG in power grids. These advantages of DG installation could only be accomplished through the optimal planning of size and placement. The DG is generally represented as a negative power injection on the radial feeders of the distribution systems. This operation is in parallel with system and independent of the terminal bus voltage.

C. Advantages of Distribution Generation

Since distributed generation (DG) was first utilized in power systems, its many advantages have been recognized. These include improving system reliability and continuity of service, enhancing voltage and load protection sensitivity, reducing the congestion and expansion of transmission and distribution networks, reducing power losses, reducing energy costs through combined heat and power generation, avoiding electricity transmission costs and less exposure to price volatility and improving the overall system performance. Due to various operational and practical requirements, the importance of DG utilization in power networks is increasingly acknowledged.

Finally, DG technologies cause lower rate of pollution to the environment with higher efficiency such as combined heat and power and micro-turbines.

D. Applications of Distribution Generation

Supplying peaking power to reduce the cost of electricity, reduce environmental emissions through clean and renewable technologies (Green Power), combined heat and power (CHP), high level of reliability and quality of supplied power and deferral of the transmission and distribution line investment through improved load ability are the major applications of the DG. Other than these applications, the major application of DG in the deregulated environment lies in the form of ancillary services. These ancillary services include spinning and non-spinning reserves, reactive power supply and voltage control etc.

IV. LOAD FLOW SOLUTION OF RADIAL DISTRIBUTED NETWORK

Traditional transmission system load flow methods like Gauss-Siedel and Newton Raphson methods cannot be apply for distribution systems as R/X ratio of the distribution network is higher than compared to transmission system. Load flow studies in distribution systems are not much popular compared to load flow studies in transmission system. In this paper, “Simple and efficient method for load flow solution in distribution network” [7] has been utilized for conducting load flow studies for proposed IEEE-15, IEEE-33 and IEEE-86 bus system for obtaining solution for optimum sizing and optimum location of DG’s.

This proposed method involves only evaluation of a simple algebraic expression of voltage magnitudes and will not involve any trigonometric equations and which is in contrary to the standard load flow solutions. Topology based approach is used for evaluating equivalent load at every node. The features of this method are robustness, very efficient and uses less computer memory. Convergence is always guaranteed. The assumptions are that the distribution system is balanced, line shunt capacitance is negligible at the distribution voltage level.

A. Solution Methodology

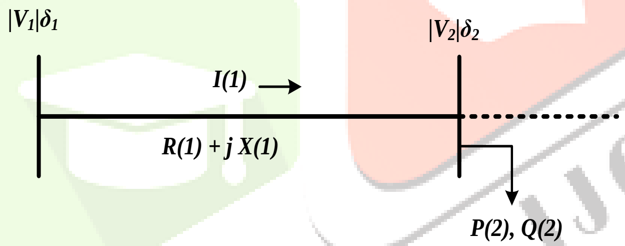

Figure 1. Electrical equivalent of IEEE 15 Bus

From the above electrical equivalent shown in figure 2, we can right

$$I(1)= \frac{|V(1)|\angle\delta(1) - |V(2)|\angle\delta(2)}{R(1) + jX(1)} \qquad (1)$$

$$P(2) - jQ(2) = V^*(2)I(1) \qquad (2)$$

$$I(1) = \frac{P(2)-jQ(2)}{V^*(2)} \qquad (3)$$

From equations (1) and (3), we get

$$\frac{|V(1)|\angle\delta(1) - |V(2)|\angle\delta(2)}{R(1) + jX(1)} = \frac{P(2)-jQ(2)}{V^*(2)}$$

Therefore

$$|V(1)||V(2)|\angle\delta(1) - \angle\delta(2) - |V(2)|^2 = [P(2) - jQ(2)][R(1) + jX(1)]$$

Therefore

$$|V(1)||V(2)|cos[\angle\delta(1) - \angle\delta(2) - |V(2)|^2] + j|V(1)||V(2)|sin[\angle\delta(1) - \angle\delta(2)] = [P(2)R(1) + Q(2)X(1)] + j[P(2)X(1) - Q2R(1)] \quad (4)$$

By separating real and imaginary parts from the equation (4), we get

$$|V(1)||V(2)|cos[\angle\delta(1) - \angle\delta(2) - |V(2)|^2] = P(2)R(1) + Q(2)X(1) \quad (5)$$

and

$$|V(1)||V(2)|sin[\angle\delta(1) - \angle\delta(2)] = P(2)X(1) - Q2R(1) \quad (6)$$

Squaring and adding the above equations (5) and (6), we get

$$|V(1)|^2|V(2)|^2 = [|V(2)|^2 + P(2)R(1) + Q(2)X(1)]^2 + [P(2)X(1) - Q2R(1)]^2 \quad (7)$$

By solving the above equation we get

$$|V(2)| = \{[(P(2)R(1) + Q(2)X(1) - 0.5|V(1)|^2 - (R^2(1) + (X^2(1))(P^2(2) + (Q^2(2))]^{1/2} - (P(2)R(1) + Q(2)X(1) - 0.5|V(1)|^2)\}^{1/2} \quad (8)$$

Where P(2) and Q(2) are total real and reactive power loads fed through node 2.

P(2) = sum of the real power loads of all the nodes beyond node 2 + real power load of node 2 itself + sum of real power losses of the branches beyond node 2.

Q(2) = sum of the reactive power loads of all the nodes beyond node 2 + reactive power load of node 2 itself + sum of reactive power losses of the branches beyond node 2.

The above equation (8) in generalized form can be written as

$$V(m2) = [B(j) - A(j)]^{1/2}$$

Where

$$A(j) = P(m2)^*R(j) + Q(m2)^*X(j) - 0.5^*|V(m1)|^2 \quad (9)$$

$$B(j) = [A^2(j) - (R^2(j) + X^3(j)^*(P^2(m2) + (Q^2(m2))]^{1/2} \quad (10)$$

Where j is the branch number, m1 and m2 are sending-end and receiving-end nodes respectively.

Real and reactive power losses in branch 1 can be given as

$$LP(1) = \frac{R(1)^*[P^2(2) + Q^2(2)]}{|V(2)|^2} \quad (11)$$

$$LQ(1) = \frac{X(1)^*[P^2(2) + Q^2(2)]}{|V(2)|^2} \quad (12)$$

Equation (11) & (12) can written in generalized form as

$$LP(j) = \frac{R(j)^*[P^2(m2) + Q^2(m2)]}{|V(m2)|^2} \quad (13)$$

$$LQ(j) = \frac{X(j)^*[P^2(m2) + Q^2(m2)]}{|V(m2)|^2} \quad (14)$$

Where

LP(j) Real power loss of branch j

LP(j) Reactive power loss of branch j

Two independent algorithms are used one for identification of nodes and branches beyond a particular node which helps in computing the exact load feeding through the particular node. Another algorithm is for conducting load flow calculations.

V. ANT COLONY OPTIMIZATION

A. Overview of Ant Colony Search Algorithm

Ant Colony Optimization (ACO) take inspiration from the behavior of real ant colonies for studying artificial systems and which are used to solve discrete optimization problems. It was first introduced by Marco Dorigo in 1992. It was initially applied for solving Traveling Salesman Problem. Natural behavior of ants have inspired scientists to mimic insect operational methods to solve real-life complex optimization problems. Scientists have begun to observe ant behavior to understand their means of communication. Ant-based behavioral patterns to address combinatorial problems - It was first proposed by Marco Dorigo[8].

The ant colony algorithm is an algorithm for finding optimal paths that is based on the behavior of ants searching for food. At first, the ants wander randomly. When an ant finds a source of food, it walks back to the colony leaving "markers" (pheromones) that show the path has food. When other ants come across the markers, they are likely to follow the path with a certain probability. If they do, they then populate the path with their own markers as they bring the food back. As more ants find the path, it gets stronger until there are a couple streams of ants traveling to various food sources near the colony.

Because the ants drop pheromones every time they bring food, shorter paths are more likely to be stronger, hence optimizing the "solution".

Once the food source is depleted, the route is no longer populated with pheromones and slowly decays.

Because the ant-colony works on a very dynamic system, the ant colony algorithm works very well in graphs with changing topologies. Examples of such systems include computer networks and artificial intelligence simulations of workers.

B. Applications of ACO

Some of the applications of ACO are

- Travelling Salesman Problem
- Assignment Problems
- Scheduling Problems
- Vehicle Routing Problems
- Sequential Ordering Problem (SOP)
- The resource constraint project
- scheduling (RCPS)
- Open Shop Scheduling Problem (OSS)

C. Convergence IN ACO

ACO algorithms are stochastic search procedures in which the pheromone update could prevent them from ever reaching an optimum. When considering a stochastic optimization algorithm, there are at least two possible types of convergence that can be considered [1]:

i). Convergence in value.

ii). Convergence in solution.

In convergence in value, the evaluation of probability that the algorithm will generate an optimal solution at least once. On the contrary, convergence in solution the evaluation of probability that the algorithm reaches a state which keeps generating the same optimal solution.

D. Advantages and Disadvantages of ACO

Advantages of the Ant Colony Optimization

- Inherent parallelism
- Positive Feedback accounts for rapid discovery of good solutions
- Efficient for Traveling Salesman Problem and similar problems
- Can be used in dynamic applications (adapts to changes such as new distances, etc)

Disadvantages of the Ant Colony Optimization

- Theoretical analysis is difficult
- Sequences of random decisions (not independent)
- Probability distribution changes by iteration

- Research is experimental rather than theoretical
- Time to convergence uncertain (but convergence is guaranteed!)

E. Mathematical Formula for ACSA

The state transition rule used by the ants system, called a random proportional rule, is given in Equation (14), which gives the probability of ant k at node r to choose the destination node s at a with probability P_k (r,s).

$$P_k(r,s) = \frac{\tau(r,s)^{\alpha}\eta(r,s)^{\beta}}{\Sigma_{u\epsilon M_k}\tau(r,u)^{\alpha}\eta(r,u)^{\beta}}, \qquad for\ S\epsilon M_k \qquad (14)$$

$$P_k(r,s) = 0 \qquad otherwise$$

Where

α= degree of pheromone

β= degree of visibility

uϵM_k= a choice that belongs any k when he was at node r.

Ant k at node r will contain all the nodes that can be visited directly connected to the node r, except nodes that are already visited. Visibility usually be replaced with 1/(distance between node r to node s).

The ant k while passing through its path will leave some pheromone. The quantity of pheromone that contained in the path segment i-j after left by the ant k is given by the formula (15)

$$\tau_{i,j} \leftarrow \tau_{i,j} + \Delta\tau^k \qquad (15)$$

With the increased value of pheromone deposit in the path segment i-j, the probability of choosing this path segment by other ants will increases.

While constructing its tour, each ant modifies the pheromone by the local updating rule[. Once a node is passed then the pheromone evaporation will occur with the local updating rule shown in formula 16[23].

$$\tau_{i,j} \leftarrow (1-\rho)\tau_{i,j} + \rho\tau_0 \qquad (16)$$

where τ_0 the initial pheromone has a value and ρ is a heuristically defined parameter known as evaporation parameter; the local updating rule is intended to shuffle the search process. Hence, the desirability of paths can be dynamically changed. The nodes visited earlier by a certain ant can be also explored later by other ants. The search space can be therefore extended. Furthermore, in so doing, ants will make a better use of pheromone information. Without local updating, all ants would search in a narrow neighborhood of the best previous tour. Most ACO algorithms uses variations of update rules mentioned by Marco Dorigo [9].

When tours are completed, the global updating rule or iteration best (IB) can be applied to edges belonging to the best ant tour. This is given by formula (17)[10].

$$\tau_{i,j} \leftarrow (1-\delta)\tau_{i,j} + \sigma\delta^{-1} \qquad (17)$$

Where

δ = Distance of the globally or iteration best tour

σ= Pheramone decay parameter

This rule is intended to provide a greater amount of pheromone to shorter tour. The IB-update rule introduces a much stronger bias towards the good solutions. However, this increases the danger of premature convergence [9].

VI. OPTIMAL ALLOCATION AND SIZING OF DISTRIBUTION GENERATION IN RADIAL DISTRIBUTION SYSTEM USING ANT COLONY SEARCH ALGORITHM.

A. Consideration

The values and constraints that are considered in load flow calculations and in Ant colony search algorithm for different IEEE bus system are tabulated in the table 1 based on size of the proposed radial distribution system for faster computing time and early convergence.

Table 1: Considerations

	IEEE 15-Bus	IEEE 33-Bus	IEEE 85-Bus
No. of Ants	150	150	300
No. of Iterations	75	75	150
Degree of Pheramone (α)	1	1	1
Degree of Visibility (β)	2	2	2
Evaration rate (σ)	0.5	0.5	0.5
Smax in KVA	1000	1000	1000
Smin in KVA	300	300	50
Vmax in p.u	1.05	1.05	1.05
Vmin in p.u	0.95	0.95	0.95

B. Algorithm for Optimal Allocation & Sizing of DG

i. Read the bus data, line data and load data for finding the voltages at each node and losses in all the lines.

ii. Run the distribution load for a distribution system without DG.

iii. Generate the Ant for first iteration.

iv. Calculate the probability of pheromone path among various buses and sizes of DGs by using equation (5).

v. Run the distribution load flow program for complete tour of ants and calculate the line losses and voltage profile.

vi. Check the required constraints and update the pheromone matrix.

vii. The pheromone matrix is modified regarding results of loss calculation.

viii. Repeat the steps from (5) to (8) for next iteration.

ix. Check the convergence condition. If satisfied, print the results otherwise go to step 4.

C. Simulation Results

The ACO algorithm is applied to determine the optimum location and sizing of distribution generators in the IEEE 15-bus, 33-bus and 85-bus radial distribution system to reduce the real and reactive power losses and to improve the voltage profile of the proposed radial distribution system. The results are as follows

D. Results of IEEE 15-BUS System

This system consists of a single main feeder and five laterals. The total load demand is 1572 KVA with minimum bus voltage of 0.9445 p.u. The total real and reactive power losses are 59.58 KW and 55.52 KVAR respectively. The optimal location & size of DG's, total real & reactive power losses and minimum and maximum voltages with placement 1No, 2No's and 3Nos are shown in the be Table 2.

Table 2 Results of IEEE 15-bus radial distribution system with 1No, 2Nos and 3Nos DG's

No. of DGs	1		2		3	
DG1 at Bus No	4	1000.00	6	813.33	6	626.67
DG2 at Bus No			4	860.00	11	346.67
DG3 at Bus No					4	766.67
Apparent Power loss in KVA	22.82		7.88		3.56	
Real Power loss in KW	17.65		6.30		2.90	
Reactive Power loss in KVAR	14.33		4.69		2.06	
Maximum Voltage in PU	1.0000		1.0008		1.0029	
Minimum Voltage in PU	0.9729		0.9824		0.9955	

The voltage at each node with and without DG's for 1No, 2Nos and 3Nos DG's are graphically represented in the figure 3, figure 5 and figure 7 respectively. The total power losses evaluated for each iteration for 1No, 2Nos and 3Nos DG's are shown in the figure 4, figure 6 and figure 8 respectively.

The percentage decrease in power losses and percentage increase in minimum voltage with different number of distribution generators are shown in the Table 3.

Table 3 Percentage change in Power Losses and Voltage in IEEE 15-Bus System

No. of DGs	1	2	3
Decrease in Power Losses	71.98%	90.32%	95.63%
Increase in Minimum Volatge	3.01%	4.01%	5.40%

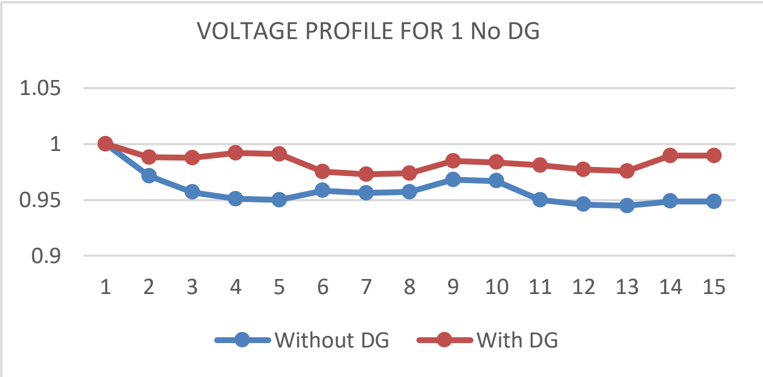

Figure 3. Comparison of voltages with and without DG's with 1No DG in IEEE 15-Bus System

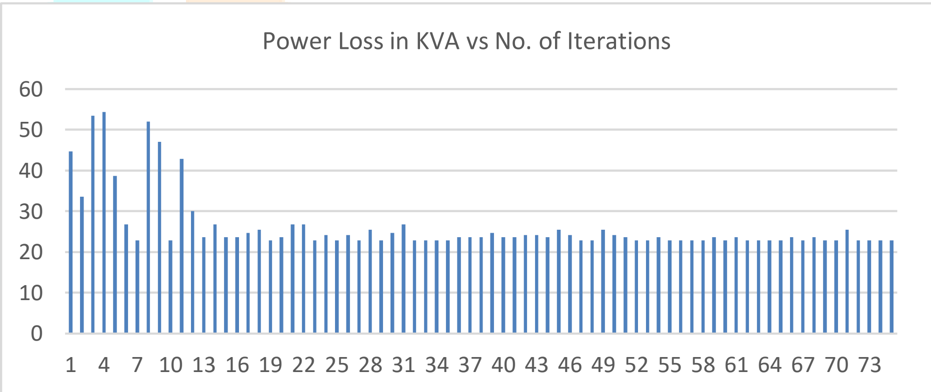

Figure 4. Total power loss with 1No DG in the IEEE 15-bus system with respect to each iteration

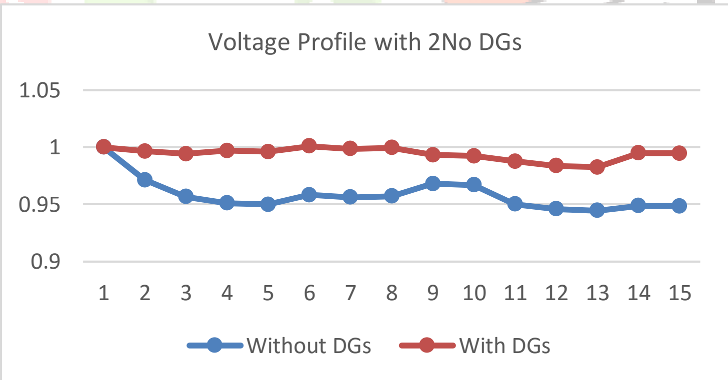

Figure 5. Comparison of voltages with and without DG's with 2No DG in IEEE15-Bus System

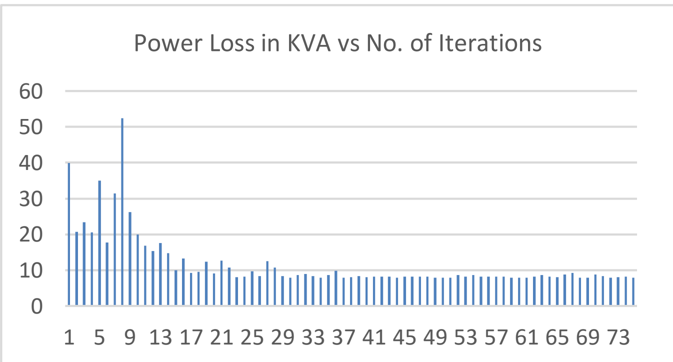

Figure 6. Total power loss with 2No DG's in the IEEE 15-bus system with respect to each iteration

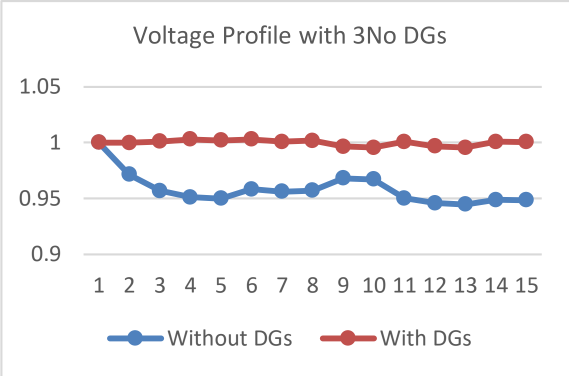

Figure 7. Comparison of voltages with and without DG's with 3No DG in IEEE15-Bus System

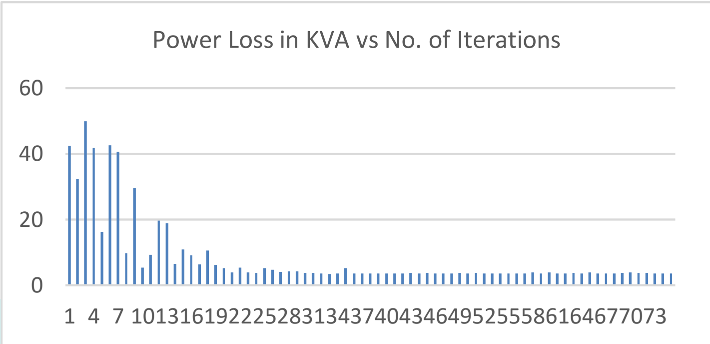

Figure 8. Total power loss with 3No DG's in the IEEE 15-bus system with respect to each iteration

E. RESULTS IN IEEE 33-BUS SYSTEM

This system consists of a single main feeder and three laterals. The total load demand is 4549 KVA with minimum bus voltage of 0.8772 p.u. The total real and reactive power losses are 296.74 KW and 196.58 KVAR respectively. The optimal location & size of DG's, total real & reactive power losses and minimum and maximum voltages with 2Nos, 4No's and 6Nos are shown in the Table 4.

Table 4 Results of IEEE 33-bus radial distribution system with 2Nos, 4Nos and 6Nos DG's

No. of DGs	2		4		6	
DG1 at Bus No	15	703.03	12	766.67	32	745.45
DG2 at Bus No	31	936.36	31	745.45	7	342.42
DG3 at Bus No			30	745.45	13	745.45
DG4 at Bus No			24	766.67	29	766.67
DG5 at Bus No					25	321.21
DG6 at Bus No					24	724.24
Apparent Power loss in KVA	86.01		27.36		12.14	
Real Power loss in KW	71.15		21.46		9.16	
Reactive Power loss in KVAR	46.60		16.17		7.69	
Maximum Voltage in PU	1.0000		1.0000		1.0035	
Minimum Voltage in PU	0.9587		0.9661		0.9877	

The voltage at each node with and without DG's for 2No, 4Nos and 6Nos DG's are graphically represented in the figure 9, figure 11 and figure 13 respectively. The total power losses evaluated for each iteration for 2No, 4Nos and 6Nos DG's are shown in the figure 10, figure 12 and figure 14 respectively. The percentage decrease in power losses and percentage increase in minimum voltage with different number of distribution generators are shown in the Table 5.

Table 5 Percentage change in Power Losses and Voltage in IEEE 33-Bus System

No. of DGs	2	4	6
Decrease in Power Losses	76.16%	92.77%	96.63%
Increase in Minimum Voltage	9.29%	10.13%	12.60%

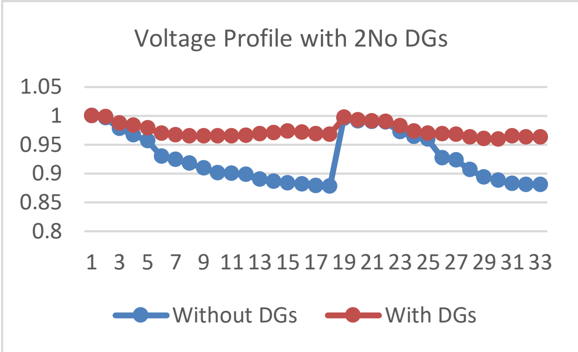

Figure 9. Comparison of voltages with and without DG's with 2No DG in IEEE 33-Bus System

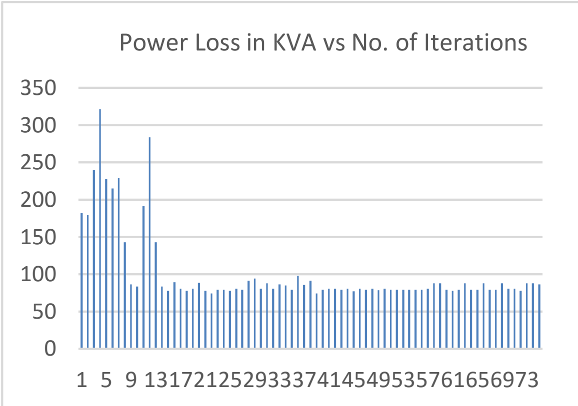

Figure 10. Total power loss with 2No DG's in the IEEE 33-bus system with respect to each iteration

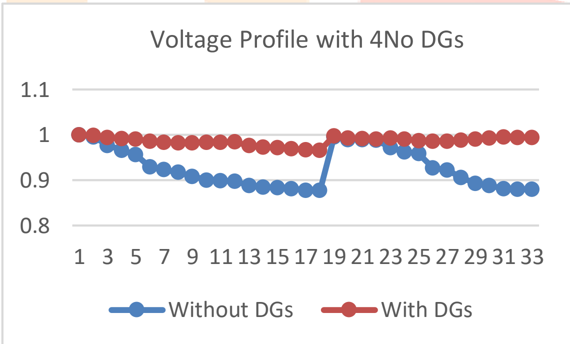

Figure 11. Comparison of voltages with and without DG's with 4No DG's in IEEE 33-Bus System

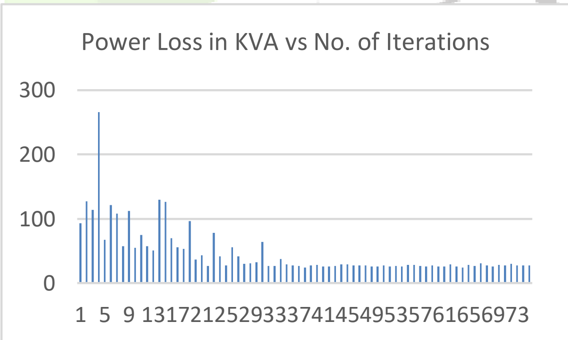

Figure 12. Total power loss with 4No DG's in the IEEE 33-bus system with respect to each iteration

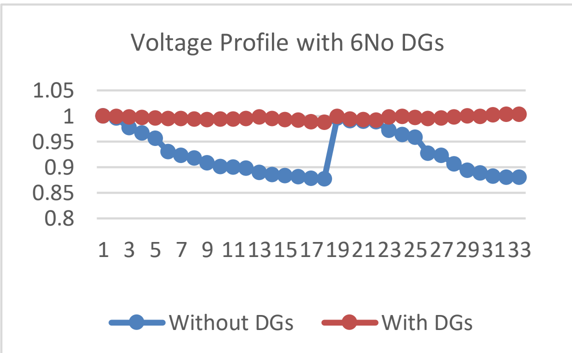

Figure 13. Comparison of voltages with and without DG's with 6No DG's in IEEE 33-Bus System

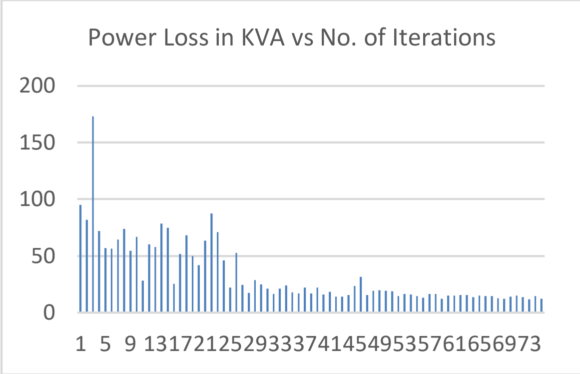

Figure 14. Total power loss with 6No DG's in the IEEE 33-bus system with respect to each iteration

F. Results In IEEE 85-BUS System

The total load demand is 3672 KVA with minimum bus voltage of 0.8719 p.u. The total real and reactive power losses are 295.12 KW and 186.06 KVAR respectively. The optimal location & size of DG's, total real & reactive power losses and minimum and maximum voltages with placement 1No is shown in the Table 6.

Table 6 Results of IEEE 85-bus radial distribution system with 1No DG

No. of DGs	8	
DG1 at Bus No	69	284.71
DG2 at Bus No	53	284.71
DG3 at Bus No	58	307.06
DG4 at Bus No	10	228.82
DG5 at Bus No	13	262.35
DG6 at Bus No	80	307.06
DG7 at Bus No	32	787.65
DG8 at Bus No	67	307.06
Apparent Power loss in KVA	11.31	
Real Power loss in KW	9.96	
Reactive Power loss in KVAR	5.23	
Maximum Voltage in PU	1.0000	
Minimum Voltage in PU	0.9883	

The voltage at each node with and without DG's for 1No DG is graphically represented in the figure 16. The total power losses evaluated for each iteration for 1No DG is shown in the figure 17.

The percentage decrease in power losses and percentage increase in minimum voltage with different number of distribution generators are shown in the Table 7.

Table 7 Percentage change in Power Losses and Voltage in IEEE 85-Bus System

No. of DGs	1
Decrease in Power Losses	96.77%
Increase in Minimum Volatge	13.35%

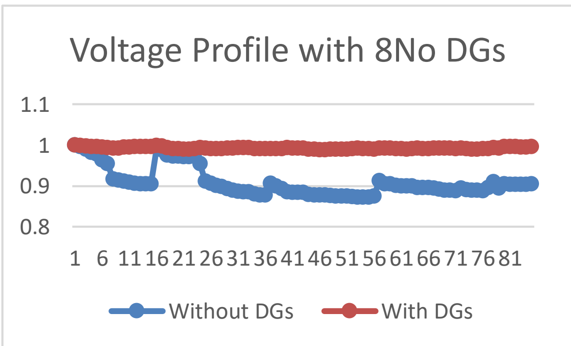

Figure 16. Comparison of voltages with and without DG's with 8No DG's in IEEE 85-Bus System

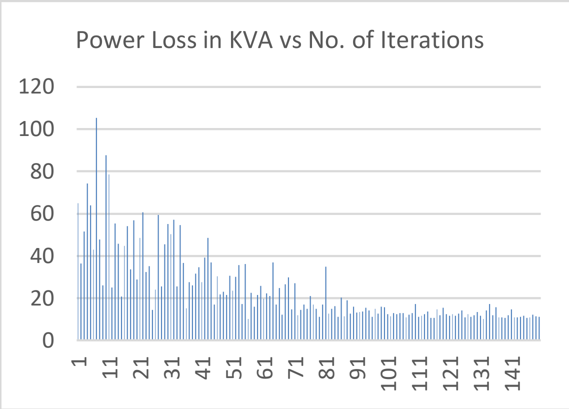

Figure 17. Total power loss with 8No DG's in the IEEE 85-bus system with respect to each iteration

CONCLUSION

The results are obtained for IEEE 15-Bus, IEEE 33-Bus and IEEE 85-Bus radial system with different number of DG's by applying Ant colony search Algorithm. The optimal location and size of the DG's are arrived and there is significant reduction in real and reactive power losses. The voltage at each node is also improved and observed that the variation of bus voltages at each node are reduced and thus making the radial distribution system to operate at near rated voltage.

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