*i*Journals: International Journal of Software & Hardware Research in Engineering (IJSHRE)
ISSN-2347-4890
Volume 10 Issue 7 July 2022

# Power System Source Optimum Distribution Using Ant-Colony Optimization Method

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**Abstract-**

Distributed generators have gained more attention as it uses renewable and non-renewable energy sources. Distributed generators (DG) can be a) renewable energy sources, such as: Wind turbines, Solar photovoltaic, Biomass energy sources or b) non-renewable energy sources such as: Diesel generator, Small turbines. Distributed generators are neither centrally placed nor dispatchable. It is scattered within the distribution system at or near load Centre. DGs incorporation in distribution system results in increase in the feeder capacity, higher reliability, lowers systems losses, improves voltage profile and improves voltage stability of the system and lowers the peak demand resulting into increase in the life of system equipment and hence more number of customers can be served. To avail these merits, one has to find out the appropriate capacity and location of DG, otherwise higher DG capacity results into higher power losses and increase of system voltage. The Ant-Colony Optimum (ACO) based totally most fantastic DG parameters estimator is designed the makes use of MATLAB programming algorithm. It has been proved that this optimization set of rules is pretty effectives for hastily locating the changes required in insertion of greater DG's location, voltages and electricity rankings in each the simulated and real-international electricity device scenarios taken into consideration.

**Keywords:** Ant-Colony Algorithm, Distributed generator, Optimum Distribution, Power source.

## Introduction

The DGs size should be such that it is equal to the total load of the system plus total system losses. Reverse power flow results due to higher capacity of DG from substation to the source node. In the literature three methods are adopted to find the optimum size of DGs, they are: analytical, heuristic and optimization techniques. Analytical method requires repetitive derivation of current and voltage after placement of DG, which requires more time. Heuristic methods are simple but the results obtained from heuristic algorithms are not guaranteed to be optimal. Optimization techniques can give the best solution within short duration of time for a given distribution network.

A study by the Electric Power Research Institute (EPRI) indicates that by 2010, 25% of the new generation will be distributed, a study by the Natural Gas Foundation concluded that this figure could be as high as 30% [1]. The European Renewable Energy Study (TERES), commissioned by the European Union (EU) to examine the feasibility of EU CO2-reduction goals and the EU renewable energy targets, found that around 60% of the renewable energy potential that can be utilized until 2010 can be categorized as decentralized power sources [2].The parameters for distributed generation (DG) used in the literature, however, are not consistent. This paper presents a discussion of the relevant aspects of DG and provides the required parameters.

During the last two decades, connection of Distribution Generation (DG) units on distribution feeders has significantly evolved. Unlike shunt capacitors, DG units are not limited to reactive power generation as they can deal with real and reactive power at the same time[3]. To this end, connection of DG units on distribution feeders has a wide impact on the performance of distribution network. With proper installation of DG systems, significant benefits could be acquired in terms of reducing power and energy losses, releasing KVA capacity, improving voltage profile, real and reactive power flow control, improving network reliability amongst others[4,5].

Many works dealing with optimal sizing and location of DG units on radial distribution feeders are reviewed in this chapter. The work of Willis [6] who used the uniformly distributed load model in discussing the relation between RPF and the sizing and location of DG units provides a suitable starting point. He presented a concept called “Zero Point Analysis” and applied it on the feeder. The concept focuses on a point on the feeder (if it exists) where power flow is zero due to the DG unit output. Accordingly, he put the impact of DG units into two categories: 1. The output of the DG unit is less than the total load demand of the downstream nodes from the point of common coupling (PCC) to the end of the feeder. In this case the power flow in the line sections between the substation and the PCC is reduced. A model of uniformly distributed feeder with 2miles length and 4MW total demand is taken as example. A DG unit of 1MW is connected 1mile from the substation.

Willis [6] analyzed the impact of the DG unit on the line losses in a similar way to the old 2/3 rule-of-thumb used with capacitors placement on uniformly distributed feeders. He suggested the same rule for the DG unit by sizing it to 2/3 of the total feeder load, at 2/3 the distance from the substation. The method combines almost all of the shortcomings been stated so far in the previous works. Hoff and Shunger [7] developed a method to simulate the line peak power and energy loss savings based on the daily load and the PVDG unit output along with few distribution system characteristics. To calculate the line power losses on 3-phase radial distribution feeder, the basic equation “3.IF2.R” is applied. IF and R are the 1-phase instantaneous current and the resistance of the line respectively. Hence, the instantaneous line power loss saving (SL) in a line section affected by PVDG unit is equal to the difference between losses before and after connecting PVDG unit(s).

The main objective of this work is to minimize the active power loss and to improve voltage profile of overall system by optimal sizing and sitting of DG. This work will present application of different optimization technique –namely Ant Colony optimization (ACO) for optimal placement of distributed generators. The methods will be tested with IEEE standard test cases of radial distribution network and the results obtained by algorithms will be comparedwithnon-optimal solutions.

**Methodology**

The methodology includes the load flow analysis and the ACO using MATLAB programming.In realistic eventualities, it isn't always viable to install the DGs on each load bus to decrease the losses.

In spite of several blessings, set up of DGs to the energy grid requires careful issues for several elements which includes:

- Stability
- Reliability
- Protection coordination
- Power loss
- Power pleasant problems

Most of all, before multiple DGs are related to the energy grid, the choice in their most fulfilling places and sizes may be very crucial in order to maximize the useful outcomes of the DGs.

In this work, will apply the ACO technique to minimize the losses and reduce the general generation price.

**Ant Colony Optimization:**

Ant Colony Optimization (ACO) [13] is a metaheuristic for solving hard combinatorial optimization problems. The inspiring source of ACO is the pheromone trail laying and following behavior of real ants, which use pheromones as a communication medium. In analogy to the biological example, ACO is based on indirect communication within a colony of simple agents, called (artificial) ants, mediated by (artificial) pheromone trails. The pheromone trails in ACO serve as a distributed, numerical information, which the ants use to probabilistically construct solutions to the problem being solved and which the ants adapt during the algorithm’s execution to reflect their search experience.

Artificial ants used in ACO are stochastic solution construction procedures that probabilistically build a solution by iteratively adding solution components to partial solutions by taking into account (i) heuristic information about the problem instance being solved, if available, and (ii) Algorithm align by using Ant Colony Optimization Approach: (artificial) pheromone trails which change dynamically at run-time to reflect the agents' acquired search experience.

A stochastic component in ACO allows the ants to build a wide variety of different solutions and hence to explore a much larger number of solutions than greedy heuristics. At the same time, the use of heuristic information, which is readily available for many problems, can guide the ants towards the most promising solutions. More important, the ants' search experience can be used to influence, in a way reminiscent of reinforcement learning, the solution construction in future iterations of the algorithm. Additionally, the use of a colony of ants can give the algorithm increased robustness and in many ACO applications the collective interaction of a population of agents is needed to efficiently solve a problem.

The domain of application of ACO algorithms is vast. In principle, ACO can be applied to any discrete optimization problem for which some solution construction mechanism can be conceived.

In the following of this section, we first define a generic problem representation that the ants in ACO may exploit to construct solutions, and then we define the ACO metaheuristic.

The (ACO) combines both algorithms evolution and particle dynamics. This targets to make use of ability of ACO to change social records and best capability in finding a new answer by using dispersal and removal.

For initialization, the user selects S, $N_s$, $N_c$, $N_{re}$, $N_{ed}$, $P_{ed}$, $C_1$, $C_2$, $R_1$, $R_2$and c(i), i= 1, 2 . . . S. Also initialize the Position $P^i_{n,1,1,1}$, i= 1, 2 . . . S and Velocity randomly initialized. The (ACO) models of Population dynamics, searching, reproduction, elimination and dispersal oriented by ACO is given below (Initially, j = k = ell = 0). Implicit subscribes will be dropped for simplicity.

1. Initialize parameters n, S, N**c**, N**s**, N**re**, N**ed**, P**ed**,c(i)(i= 1, 2 . . . S), Delta, C1, C2, R1, R2. where,
   - n : Dimension of the search space,
   - S : The number of particle in the population,
   - $S_r$: Half the total number of particle,
   - $N_s$: Maximum number of atep length,
   - $N_c$: no. of steps,
   - $N_{re}$: The number of reproduction steps,
   - $N_{ed}$: Elimination and dispersal events,
   - $P_{ed}$: Elimination and dispersal with probability,
   - c(i): The step size taken in the random direction,
   - C1, C2: ACO random parameter,
   - R1, R2: ACO random parameter.
2. Generate a random direction Delta(n,i) and position.

```
For (e l l=1 to Ned)
For (k=1 to Nre)
For (j=1 to Nc)
For (i=1 to S)
Evaluate the cost function
$J(i, j) = \text{Func}(P(i, j))$
Store the best cost function in J last\
$Jlast = J(i, j)$
```

The best cost for each particle will be selected to be the local best *J local*

$J\,local(i, j) = J\,last(i, j)$

Update position and cost function

$P(i, j+1) = P(i, j) + c(i) * \text{Delta}(n, i)$

$J(i, j+1) = \text{Func}(P(i, j+1))$

while (m <*Ns*)

```
        If $J(i, j+1) < J\ last$
        then
                $J\ last = J(i, j+1)$
Update position and cost function
        $P(i, j+1) = P(i, j+1) + c(i) * Delta(n, i)$

        $J(i, j+1) = Func(P(i, j+1))$
Evaluate the current position and local cost for each particle
        $Pcurrent(i, j+1) = P(i, j+1)$
        $Jlocal(i,j+1) = J\ last(i, j+1)$
        else
        $Pcurrent(i, j+1) = P(i, j+1)$
        $J\ local(i, j+1) = J\ last(i, j+1)$
        end if
        m = m + 1
        end while
        next$i$( next particle )
Evaluate the local best position ( $Pl\ best$ ) foreach particle and global best position ( $P\ best$). .
Evaluate the new direction for each particle
        $V = w * V + C1 * R1(Pl\ best - Pcurrent) + C2 * R2(Pgbest - Pcurrent)$ $Delta = V$

        next$j$ (next chemotactic)
        for ($I$ = 1 to $S$)

                $J^{i}_{health} = \sum_{j=1}^{N_c+1} i, j, k, ell$

        End
The Sr particle with the highest Jhealth remove and the other Sr particle with the best values copies.
        next k (next reproduction)
With probability Ped , eliminates and disperse each particle .
        next ell (next elimination)
```

## Results and Discussion

This chapter covers the results in tabular form and plots along with the discussions over the result analysis. The work consists of the thesis objective of inclusion any DG in a 57 bus system at an optimum value for which the losses and cost can be minimized. Figure 1 shows the IEEE-57 bus system:

We can see that are total 57 bus identity numbers in column 1. The remaining columns represents the respective bus voltage magnitude, voltage angle, power flow to load and the power generated at the buses and the injected MVAR if any reactive device is placed [15].

In the last rows the total losses in the 57bus system are shown. Here it can be observed that in standard 57 bus system the total losses are 27.394MW as observed by NRLF methods power flow solutions result. The total generation cost that is obtained here is 950685.6 $/hr at the given values of generator and load power values at different buses.

Table 1 here shows the result obtained using load flow analysis results for using a standard 57 bus system. This load flow is generated by using Newton Raphson load flow analysis results on MATLAB based programming platform [14].

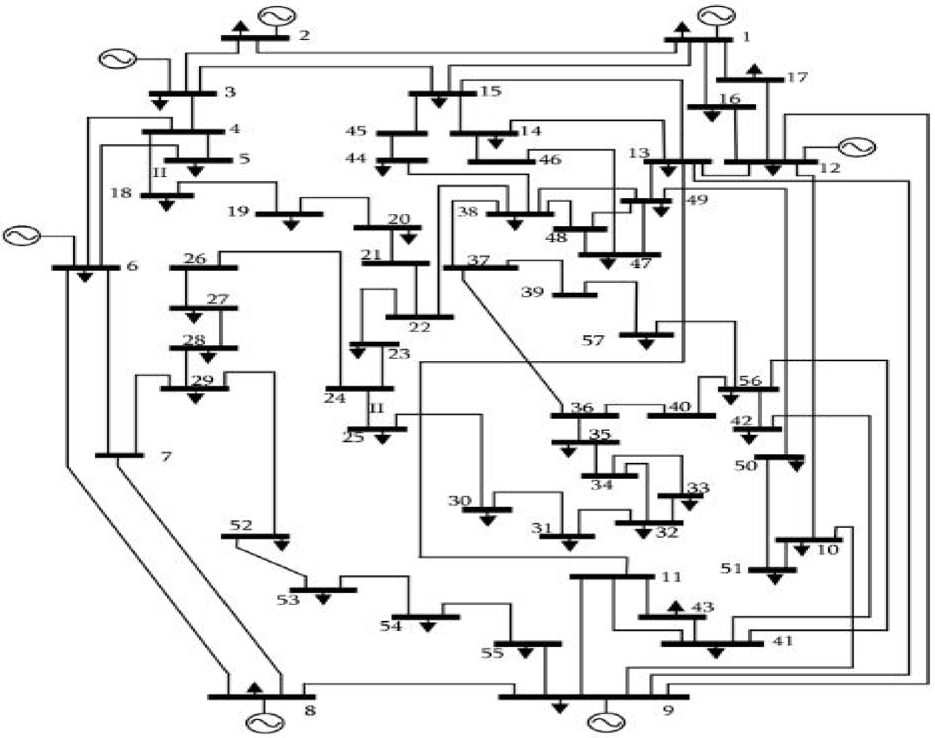

**Figure 1**IEEE benchmarked 57-bus system

Table 3 here shows the result obtained using load flow analysis results for using a standard 58 bus system that is obtained on adding a DG. This load flow is generated by using Newton Raphson load flow analysis results on MATLAB based programming platform [17]. We can see that there are total 58 bus identity numbers in column 1. The remaining columns represents the respective bus voltage magnitude, voltage angle, power flow to load and the power generated at the buses and the injected MVAR if any reactive device is placed [18]. In the last rows the total losses in the 57bus system are shown. Here it can be observed that in standard 57 bus system the total losses are 27.394MW as observed by NRLF methods power flow solutions result. The total generation cost that is obtained here is 941390.6 \$/hr at the given values of generator and load power values at different buses. The optimum value of solution set in terms of {r, a, V, P} is {66, 0.25, 1.28, 15}. That solution set represents the global best value at which the power loss are almost equivalent i.e. 27.394MW but the total cost is reduced 941390.6 \$/hr from 950685 \$/hr.

The Optimized parameter value for which minimum cost is obtained are given value along with their units.

**Optimized parameter value**

Line no.   66.00,    Distance from line: 0.25 ,   Voltage:  1.28 pu, Power:  15.00 MW
Hence it shows that if we take the 66 number line and place a DG of 15MW at the distance of 25% from the FROM bus of 66th line at voltage value of 1.28pu then minimum cost will be 941390\$/hr at its optimum result value.

Table 1: Power Flow Solution by Newton-Raphson Method for original 57bus
Maximum Power Mismatch = 1
No. of Iterations = 0

| Bus No. | Volt. Mag. | Angle Degree | Load (MW) | Load (MVAR) | Gen (MW) | Gen (MVAR) | Injected (MVAR) |
|---|---|---|---|---|---|---|---|
| 1 | 1.04 | 0 | 55 | 17 | 128.9 | -16.1 | 0 |
| 2 | 1.01 | -1.18 | 3 | 88 | 0 | -0.8 | 0 |
| 3 | 0.985 | -5.97 | 41 | 21 | 40 | -1 | 0 |
| 4 | 0.981 | -7.32 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0.976 | -8.52 | 13 | 4 | 0 | 0 | 0 |
| 6 | 0.98 | -8.65 | 75 | 2 | 0 | 0.8 | 0 |
| 7 | 0.984 | -7.58 | 0 | 0 | 0 | 0 | 0 |
| 8 | 1.005 | -4.45 | 150 | 22 | 450 | 62.1 | 0 |
| 9 | 0.98 | -9.56 | 121 | 26 | 0 | 2.2 | 0 |
| 10 | 0.986 | -11.43 | 5 | 2 | 0 | 0 | 0 |
| 11 | 0.974 | -10.17 | 0 | 0 | 0 | 0 | 0 |
| 12 | 1.015 | -10.46 | 377 | 24 | 310 | 128.5 | 0 |
| 13 | 0.979 | -9.79 | 18 | 2.3 | 0 | 0 | 0 |
| 14 | 0.97 | -9.33 | 10.5 | 5.3 | 0 | 0 | 0 |
| 15 | 0.988 | -7.18 | 22 | 5 | 0 | 0 | 0 |
| 16 | 1.013 | -8.85 | 43 | 3 | 0 | 0 | 0 |
| 17 | 1.017 | -5.39 | 42 | 8 | 0 | 0 | 0 |
| 18 | 1.001 | -11.71 | 27.2 | 9.8 | 0 | 0 | 0 |
| 19 | 0.97 | -13.2 | 3.3 | 0.6 | 0 | 0 | 0 |
| 20 | 0.964 | -13.41 | 2.3 | 1 | 0 | 0 | 0 |
| 21 | 1.008 | -12.89 | 0 | 0 | 0 | 0 | 0 |
| 22 | 1.01 | -12.84 | 0 | 0 | 0 | 0 | 0 |
| 23 | 1.008 | -12.91 | 6.3 | 2.1 | 0 | 0 | 0 |
| 24 | 0.999 | -13.25 | 0 | 0 | 0 | 0 | 0 |
| 25 | 0.982 | -18.13 | 6.3 | 3.2 | 0 | 0 | 0 |
| 26 | 0.959 | -12.95 | 0 | 0 | 0 | 0 | 0 |
| 27 | 0.982 | -11.48 | 9.3 | 0.5 | 0 | 0 | 0 |
| 28 | 0.997 | -10.45 | 4.6 | 2.3 | 0 | 0 | 0 |
| 29 | 1.01 | -9.75 | 17 | 2.6 | 0 | 0 | 0 |
| 30 | 0.962 | -18.68 | 3.6 | 1.8 | 0 | 0 | 0 |
| 31 | 0.936 | -19.34 | 5.8 | 2.9 | 0 | 0 | 0 |
| 32 | 0.949 | -18.46 | 1.6 | 0.8 | 0 | 0 | 0 |
| 33 | 0.947 | -18.5 | 3.8 | 1.9 | 0 | 0 | 0 |
| 34 | 0.959 | -14.1 | 0 | 0 | 0 | 0 | 0 |
| 35 | 0.966 | -13.86 | 6 | 3 | 0 | 0 | 0 |
| 36 | 0.976 | -13.59 | 0 | 0 | 0 | 0 | 0 |
| 37 | 0.985 | -13.41 | 0 | 0 | 0 | 0 | 0 |
| 38 | 1.013 | -12.71 | 14 | 7 | 0 | 0 | 0 |
| 39 | 0.983 | -13.46 | 0 | 0 | 0 | 0 | 0 |
| 40 | 0.973 | -13.62 | 0 | 0 | 0 | 0 | 0 |
| 41 | 0.996 | -14.05 | 6.3 | 3 | 0 | 0 | 0 |
| 42 | 0.966 | -15.5 | 7.1 | 4.4 | 0 | 0 | 0 |
| 43 | 1.01 | -11.33 | 2 | 1 | 0 | 0 | 0 |
| 44 | 1.017 | -11.86 | 12 | 1.8 | 0 | 0 | 0 |
| 45 | 1.036 | -9.25 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 46 | 1.05 | -11.89 | 0 | 0 | 0 | 0 | 0 |
| 47 | 1.033 | -12.49 | 29.7 | 11.6 | 0 | 0 | 0 |
| 48 | 1.027 | -12.59 | 0 | 0 | 0 | 0 | 0 |
| 49 | 1.036 | -12.92 | 18 | 8.5 | 0 | 0 | 0 |
| 50 | 1.023 | -13.39 | 21 | 10.5 | 0 | 0 | 0 |
| 51 | 1.052 | -12.52 | 18 | 5.3 | 0 | 0 | 0 |
| 52 | 0.98 | -11.47 | 4.9 | 2.2 | 0 | 0 | 0 |
| 53 | 0.971 | -12.23 | 20 | 10 | 0 | 0 | 0 |
| 54 | 0.996 | -11.69 | 4.1 | 1.4 | 0 | 0 | 0 |
| 55 | 1.031 | -10.78 | 6.8 | 3.4 | 0 | 0 | 0 |
| 56 | 0.968 | -16.04 | 7.6 | 2.2 | 0 | 0 | 0 |
| 57 | 0.965 | -16.56 | 6.7 | 2 | 0 | 0 | 0 |
| **Total** | **loss:** | 27.394MW | | -85.925 | MVAR | | |
| | | | | | | | |
| **Total** | **generation** | **cost** | = | 950685.6 | $/h | | |

**Table 2**: Power Flow Solution by Newton-Raphson Method for optimized 58bus
Maximum Power Mismatch = 1
No. of Iterations = 0

| **Bus No.** | **Volt. Mag.** | **Angle Degree** | **Load (MW)** | **Load (MVAR)** | **Gen (MW)** | **Gen (MVAR)** | **Injected (MVAR)** |
|---|---|---|---|---|---|---|---|
| 1 | 1.04 | 0 | 55 | 17 | 128.9 | -16.1 | 0 |
| 2 | 1.01 | -1.18 | 3 | 88 | 0 | -0.8 | 0 |
| 3 | 0.985 | -5.97 | 41 | 21 | 40 | -1 | 0 |
| 4 | 0.981 | -7.32 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0.976 | -8.52 | 13 | 4 | 0 | 0 | 0 |
| 6 | 0.98 | -8.65 | 75 | 2 | 0 | 0.8 | 0 |
| 7 | 0.984 | -7.58 | 0 | 0 | 0 | 0 | 0 |
| 8 | 1.005 | -4.45 | 150 | 22 | 450 | 62.1 | 0 |
| 9 | 0.98 | -9.56 | 121 | 26 | 0 | 2.2 | 0 |
| 10 | 0.986 | -11.43 | 5 | 2 | 0 | 0 | 0 |
| 11 | 0.974 | -10.17 | 0 | 0 | 0 | 0 | 0 |
| 12 | 1.015 | -10.46 | 377 | 24 | 310 | 128.5 | 0 |
| 13 | 0.979 | -9.79 | 18 | 2.3 | 0 | 0 | 0 |
| 14 | 0.97 | -9.33 | 10.5 | 5.3 | 0 | 0 | 0 |
| 15 | 0.988 | -7.18 | 22 | 5 | 0 | 0 | 0 |
| 16 | 1.013 | -8.85 | 43 | 3 | 0 | 0 | 0 |
| 17 | 1.017 | -5.39 | 42 | 8 | 0 | 0 | 0 |
| 18 | 1.001 | -11.71 | 27.2 | 9.8 | 0 | 0 | 0 |
| 19 | 0.97 | -13.2 | 3.3 | 0.6 | 0 | 0 | 0 |
| 20 | 0.964 | -13.41 | 2.3 | 1 | 0 | 0 | 0 |
| 21 | 1.008 | -12.89 | 0 | 0 | 0 | 0 | 0 |
| 22 | 1.01 | -12.84 | 0 | 0 | 0 | 0 | 0 |
| 23 | 1.008 | -12.91 | 6.3 | 2.1 | 0 | 0 | 0 |
| 24 | 0.999 | -13.25 | 0 | 0 | 0 | 0 | 0 |
| 25 | 0.982 | -18.13 | 6.3 | 3.2 | 0 | 0 | 0 |
| 26 | 0.959 | -12.95 | 0 | 0 | 0 | 0 | 0 |
| 27 | 0.982 | -11.48 | 9.3 | 0.5 | 0 | 0 | 0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 28 | 0.997 | -10.45 | 4.6 | 2.3 | 0 | 0 | 0 |
| 29 | 1.01 | -9.75 | 17 | 2.6 | 0 | 0 | 0 |
| 30 | 0.962 | -18.68 | 3.6 | 1.8 | 0 | 0 | 0 |
| 31 | 0.936 | -19.34 | 5.8 | 2.9 | 0 | 0 | 0 |
| 32 | 0.949 | -18.46 | 1.6 | 0.8 | 0 | 0 | 0 |
| 33 | 0.947 | -18.5 | 3.8 | 1.9 | 0 | 0 | 0 |
| 34 | 0.959 | -14.1 | 0 | 0 | 0 | 0 | 0 |
| 35 | 0.966 | -13.86 | 6 | 3 | 0 | 0 | 0 |
| 36 | 0.976 | -13.59 | 0 | 0 | 0 | 0 | 0 |
| 37 | 0.985 | -13.41 | 0 | 0 | 0 | 0 | 0 |
| 38 | 1.013 | -12.71 | 14 | 7 | 0 | 0 | 0 |
| 39 | 0.983 | -13.46 | 0 | 0 | 0 | 0 | 0 |
| 40 | 0.973 | -13.62 | 0 | 0 | 0 | 0 | 0 |
| 41 | 0.996 | -14.05 | 6.3 | 3 | 0 | 0 | 0 |
| 42 | 0.966 | -15.5 | 7.1 | 4.4 | 0 | 0 | 0 |
| 43 | 1.01 | -11.33 | 2 | 1 | 0 | 0 | 0 |
| 44 | 1.017 | -11.86 | 12 | 1.8 | 0 | 0 | 0 |
| 45 | 1.036 | -9.25 | 0 | 0 | 0 | 0 | 0 |
| 46 | 1.05 | -11.89 | 0 | 0 | 0 | 0 | 0 |
| 47 | 1.033 | -12.49 | 29.7 | 11.6 | 0 | 0 | 0 |
| 48 | 1.027 | -12.59 | 0 | 0 | 0 | 0 | 0 |
| 49 | 1.036 | -12.92 | 18 | 8.5 | 0 | 0 | 0 |
| 50 | 1.023 | -13.39 | 21 | 10.5 | 0 | 0 | 0 |
| 51 | 1.052 | -12.52 | 18 | 5.3 | 0 | 0 | 0 |
| 52 | 0.98 | -11.47 | 4.9 | 2.2 | 0 | 0 | 0 |
| 53 | 0.971 | -12.23 | 20 | 10 | 0 | 0 | 0 |
| 54 | 0.996 | -11.69 | 4.1 | 1.4 | 0 | 0 | 0 |
| 55 | 1.031 | -10.78 | 6.8 | 3.4 | 0 | 0 | 0 |
| 56 | 0.968 | -16.04 | 7.6 | 2.2 | 0 | 0 | 0 |
| 57 | 0.965 | -16.56 | 6.7 | 2 | 0 | 0 | 0 |
| 58 | 1.279 | 0 | 0 | 0 | 15 | 25.1 | 0 |
| | | | | | | | |
| **Total:** | | | **1250.8** | **336.4** | **943.9** | **200.8** | **0** |
| | | | | | | | |
| **Total** | **loss:** | 27.394MW | | 263.95MVAR | | | |
| | | | | | | | |
| **Total** | **generation** | **cost** | = | 941390.08 | $/h | | |

Figure 2 is obtained on plotting the value of minimum cost at each iteration. These values are minimum generation cost for the local best solution during the search of the ACO algorithm. Figure 4.3 is the average cost of all the DG's parameters which are updated by the ACO at every iterations [19]. It shows that the ACO search approach is converging towards minimum cost. Initially the average cost for all possible DG's at their initial random parametric values of [r a V P] is near about $1.26 \times 10^6$ $/hr but as iteration increases the cost is monotonically decreases with respect to each iterations. Hence this plot represents that the ACO is working successfully and capable of finding better minimum cost in every new iteration as compared to previous iterations.

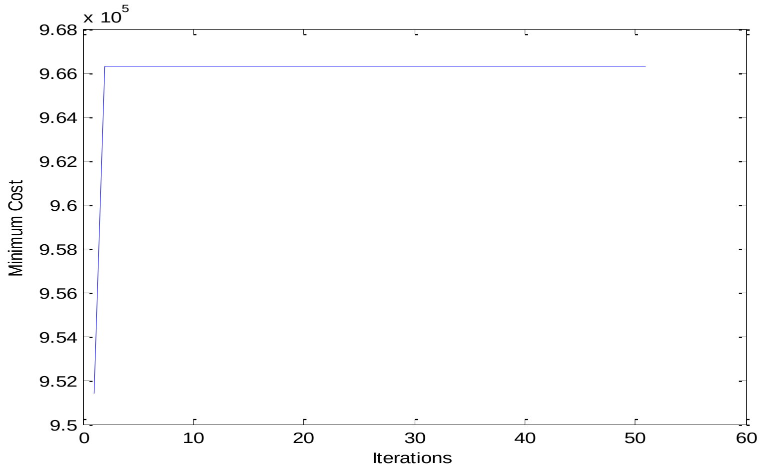

**Figure 2 Minimum cost vs. iterations**

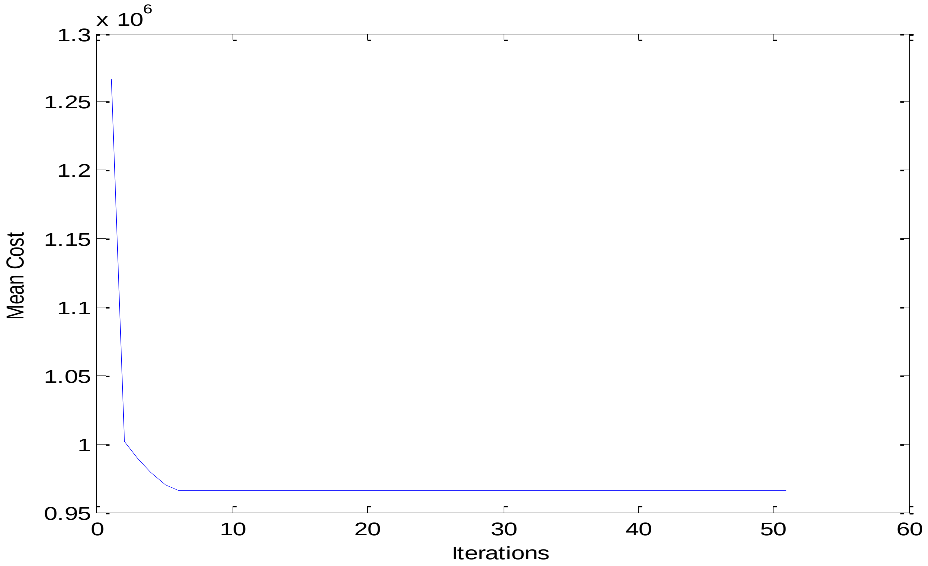

**Figure3:** Convergence Plot

It is also found in the figure 3 that the mean cost is getting saturated after near about 10 iteration and for iterations higher than 10 no better minimum cost is obtained. Thus this ACO based search is very fast to find optimum results. Although the algorithm is run for 50 iteration but such a long time is not required because this algorithm is capable finding result in very fast manner i.e. near about 5 to 10 iteration.

**Table 3:** Comparative result

| **Cost of generation in original 57 bus:**<br>950685.6 $/h | **Cost of generation in optimized 58 bus:**<br>941390.08 $/h |
|---|---|
| **Losses:**<br>27.394MW | **Losses:**<br>27.394MW |

Table 3 shows the comparison of our result obtained for ACO optimum search to get a parameter selection [r a V P] at which a minimum cost and optimum solution is to be find out [20]. It can be seen in the table 3 that the result Cost of generation in original 57 bus950685.6 $/h while the result obtained for the updated bus system with DG is 941390 $/hr. Hence this table justifies that the ACO algorithm has worked well in objective of finding optimal location of DG at keep similar losses at the value of 27.394MW.

**Table 4:** Optimized 58 bus line data

| S.No. | from | to | R | X | B/2 | Tap Ratio |
|---|---|---|---|---|---|---|
| 1. | 1 | 2 | 0.0083 | 0.028 | 0.129 | 1 |
| 2. | 2 | 3 | 0.0298 | 0.085 | 0.0818 | 1 |
| 3. | 3 | 4 | 0.0112 | 0.0366 | 0.038 | 1 |
| 4. | 4 | 5 | 0.0625 | 0.132 | 0.0258 | 1 |
| 5. | 4 | 6 | 0.043 | 0.148 | 0.0348 | 1 |
| 6. | 6 | 7 | 0.02 | 0.102 | 0.0276 | 1 |
| 7. | 6 | 8 | 0.0339 | 0.173 | 0.047 | 1 |
| 8. | 8 | 9 | 0.0099 | 0.0505 | 0.0548 | 1 |
| 9. | 9 | 10 | 0.0369 | 0.1679 | 0.044 | 1 |
| 10. | 9 | 11 | 0.0258 | 0.0848 | 0.0218 | 1 |
| 11. | 9 | 12 | 0.0648 | 0.295 | 0.0772 | 1 |
| 12. | 9 | 13 | 0.0481 | 0.158 | 0.0406 | 1 |
| 13. | 13 | 14 | 0.0132 | 0.0434 | 0.011 | 1 |
| 14. | 13 | 15 | 0.0269 | 0.0869 | 0.023 | 1 |
| 15. | 1 | 15 | 0.0178 | 0.091 | 0.0988 | 1 |
| 16. | 1 | 16 | 0.0454 | 0.206 | 0.0546 | 1 |
| 17. | 1 | 17 | 0.0238 | 0.108 | 0.0286 | 1 |
| 18. | 3 | 15 | 0.0162 | 0.053 | 0.0544 | 1 |
| 19. | 4 | 18 | 0 | 0.555 | 0 | 1 |
| 20. | 4 | 18 | 0 | 0.43 | 0 | 1 |
| 21. | 5 | 6 | 0.0302 | 0.0641 | 0.0124 | 1 |
| 22. | 7 | 8 | 0.0139 | 0.0712 | 0.0194 | 1 |
| 23. | 10 | 12 | 0.0277 | 0.1262 | 0.0328 | 1 |
| 24. | 11 | 13 | 0.0223 | 0.0732 | 0.0188 | 1 |
| 25. | 12 | 13 | 0.0178 | 0.058 | 0.0604 | 1 |
| 26. | 12 | 16 | 0.018 | 0.0813 | 0.0216 | 1 |
| 27. | 12 | 17 | 0.0397 | 0.179 | 0.0476 | 1 |
| 28. | 14 | 15 | 0.0171 | 0.0547 | 0.0148 | 1 |
| 29. | 18 | 19 | 0.461 | 0.685 | 0 | 1 |
| 30. | 19 | 20 | 0.283 | 0.434 | 0 | 1 |
| 31. | 21 | 20 | 0 | 0.7767 | 0 | 1 |
| 32. | 21 | 22 | 0.0736 | 0.117 | 0 | 1 |
| 33. | 22 | 23 | 0.0099 | 0.0152 | 0 | 1 |
| 34. | 23 | 24 | 0.166 | 0.256 | 0.0084 | 1 |
| 35. | 24 | 25 | 0 | 1.182 | 0 | 1 |
| 36. | 24 | 25 | 0 | 1.23 | 0 | 1 |
| 37. | 24 | 26 | 0 | 0.0473 | 0 | 1 |
| 38. | 26 | 27 | 0.165 | 0.254 | 0 | 1 |
| 39. | 27 | 28 | 0.0618 | 0.0954 | 0 | 1 |
| 40. | 28 | 29 | 0.0418 | 0.0587 | 0 | 1 |
| 41. | 7 | 29 | 0 | 0.0648 | 0 | 1 |
| 42. | 25 | 30 | 0.135 | 0.202 | 0 | 1 |
| 43. | 30 | 31 | 0.326 | 0.497 | 0 | 1 |
| 44. | 31 | 32 | 0.507 | 0.755 | 0 | 1 |
| 45. | 32 | 33 | 0.0392 | 0.036 | 0 | 1 |
| 46. | 34 | 32 | 0 | 0.953 | 0 | 1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 47. | 34 | 35 | 0.052 | 0.078 | 0.0032 | 1 |
| 48. | 35 | 36 | 0.043 | 0.0537 | 0.0016 | 1 |
| 49. | 36 | 37 | 0.029 | 0.0366 | 0 | 1 |
| 50. | 37 | 38 | 0.0651 | 0.1009 | 0.002 | 1 |
| 51. | 37 | 39 | 0.0239 | 0.0379 | 0 | 1 |
| 52. | 36 | 40 | 0.03 | 0.0466 | 0 | 1 |
| 53. | 22 | 38 | 0.0192 | 0.0295 | 0 | 1 |
| 54. | 11 | 41 | 0 | 0.749 | 0 | 1 |
| 55. | 41 | 42 | 0.207 | 0.352 | 0 | 1 |
| 56. | 41 | 43 | 0 | 0.412 | 0 | 1 |
| 57. | 38 | 44 | 0.0289 | 0.0585 | 0.002 | 1 |
| 58. | 15 | 45 | 0 | 0.1042 | 0 | 1 |
| 59. | 14 | 46 | 0 | 0.0735 | 0 | 1 |
| 60. | 46 | 47 | 0.023 | 0.068 | 0.0032 | 1 |
| 61. | 47 | 48 | 0.0182 | 0.0233 | 0 | 1 |
| 62. | 48 | 49 | 0.0834 | 0.129 | 0.0048 | 1 |
| 63. | 49 | 50 | 0.0801 | 0.128 | 0 | 1 |
| 64. | 50 | 51 | 0.1386 | 0.22 | 0 | 1 |
| 65. | 10 | 51 | 0 | 0.0712 | 0 | 1 |
| 66. | 13 | 58 | 0 | 0.04774 | 0 | 1 |
| 67. | 29 | 52 | 0.1442 | 0.187 | 0 | 1 |
| 68. | 52 | 53 | 0.0762 | 0.0984 | 0 | 1 |
| 69. | 53 | 54 | 0.1878 | 0.232 | 0 | 1 |
| 70. | 54 | 55 | 0.1732 | 0.2265 | 0 | 1 |
| 71. | 11 | 43 | 0 | 0.153 | 0 | 1 |
| 72. | 44 | 45 | 0.0624 | 0.1242 | 0.004 | 1 |
| 73. | 40 | 56 | 0 | 1.195 | 0 | 1 |
| 74. | 56 | 41 | 0.553 | 0.549 | 0 | 1 |
| 75. | 56 | 42 | 0.2125 | 0.354 | 0 | 1 |
| 76. | 39 | 57 | 0 | 1.355 | 0 | 1 |
| 77. | 57 | 56 | 0.174 | 0.26 | 0 | 1 |
| 78. | 38 | 49 | 0.115 | 0.177 | 0.003 | 1 |
| 79. | 38 | 48 | 0.0312 | 0.0482 | 0 | 1 |
| 80. | 9 | 55 | 0 | 0.1205 | 0 | 1 |
| 81. | 58 | 49 | 0 | 0.14326 | 0 | 1 |

Table 4 shows the line data value for updated optimized 58 system obtained on adding additional DG. The column 1 shows the FROM bus number id and column 2 shows the id number of TO bus. It has been observed that the optimized parameter value was {r a V P}:
r: Line no.   66.00
a: Distance from line: 0.25
V: Voltage:  1.28 pu
P: Power:  15.00 MW
So we can see in table 5 that at line no. 66 the 58th bus is connected from bust number 13 (from bus) and this 58 bus is acting as from bus for bus 49 as shown in highlighted texts.

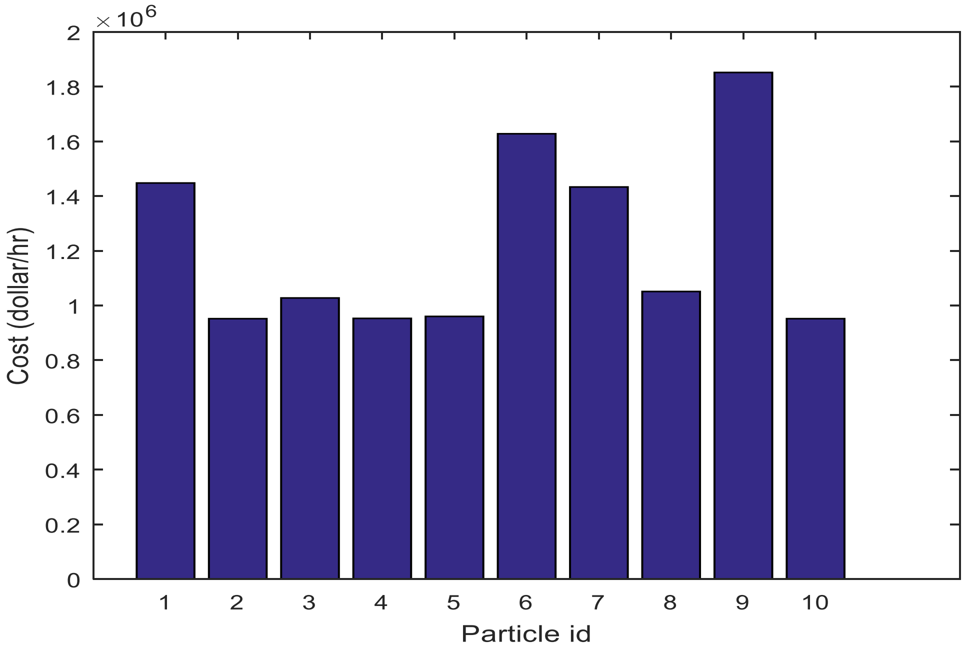

**Figure 4:** Cost obtained at different particle id solution by ACO

Figure 4 shows various cost finally obtained by 10 particle based optimized solution at the end of optimum search.

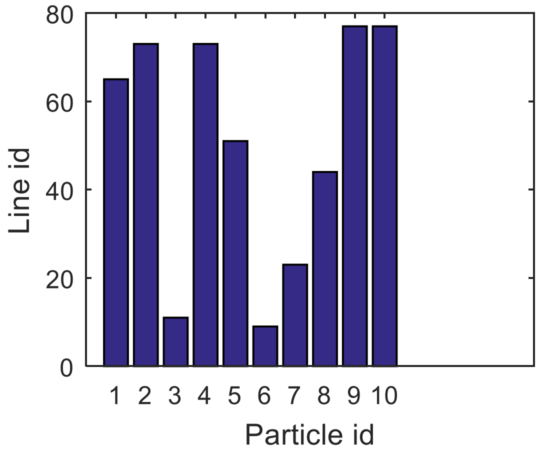

**Figure 5 a:** Line id of optimized particles

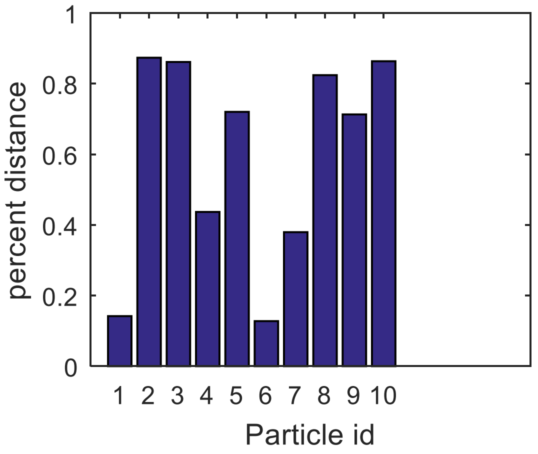

**Figure 5b:** percent distance of optimized particles

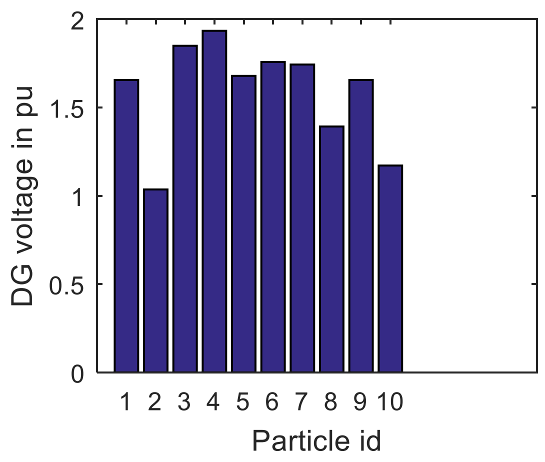

**Figure 5 c**: DG voltage of optimized particles

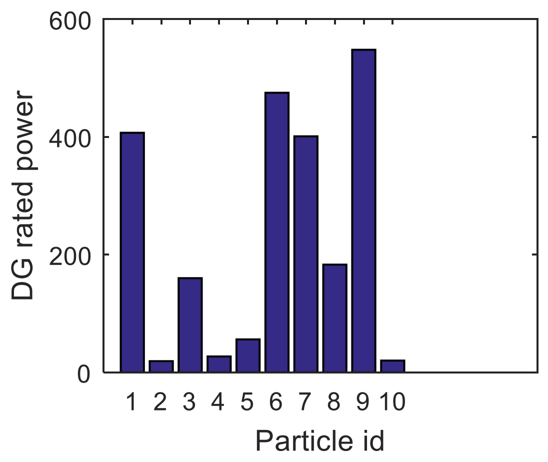

**Figure 5 d:** DG rated power of optimized particles

Figure 5 a to shows the parametric value of all the optimized 10 particle at respective id obtained on reaching the final round of optimization search in terms of DG location as per line id, its distance from to bus for line id, it voltage rating in pu and its rated power in MW.

Similarly at different iteration and number of particles several times the ACO optimization algorithm is run for several times and best optimized solutions with better cost and lower losses are considered. The comparative values wrt 57bus and optimized 58 bus with DG placement are shown in figure 6.

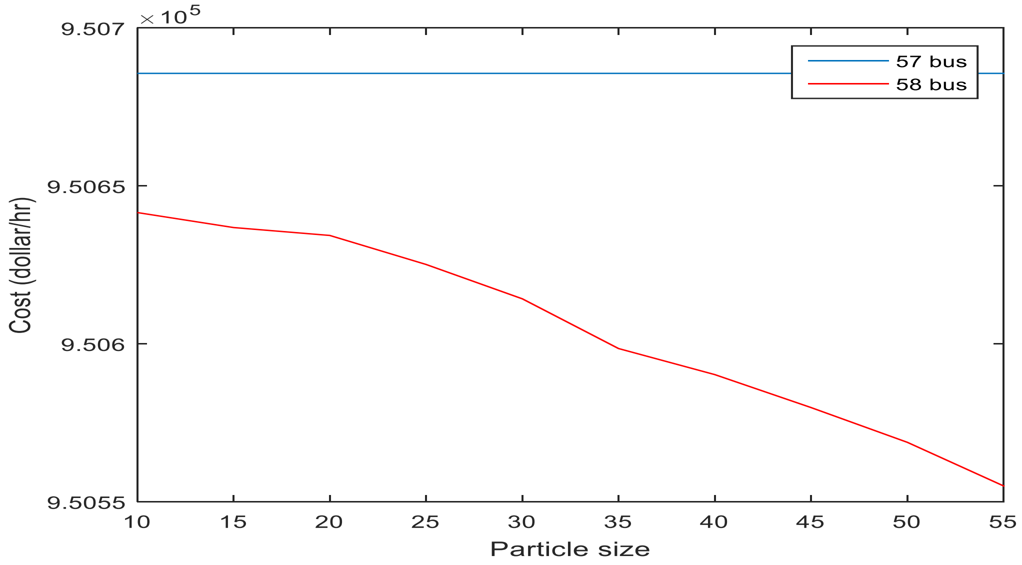

**Figure 6:** Selected optimized result with better performance cost wrt 57 (blue) and optimized 58 bus systems.

Table 5 shows the bus data of the optimized 58 bus. It consists of columns with Bus No., Bus Type, Power values, area, and voltage values with maximum and minimum values.

**Table 5:** OPTIMIZED 58 bus Bus data

| Bus No. | Bus Type | Pd | Qd | Gs | Bs | area | Vm | Va | Vmax | Vmin |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1.04 | 0 | 55 | 17 | 128.9 | -16.1 | -140 | 200 | 0 |
| 2 | 2 | 1.01 | -1.18 | 3 | 88 | 0 | -0.8 | -17 | 50 | 0 |
| 3 | 2 | 0.985 | -5.97 | 41 | 21 | 40 | -1 | -10 | 60 | 0 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 0 | 0.981 | -7.32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0.976 | -8.52 | 13 | 4 | 0 | 0 | 0 | 0 | 0 |
| 6 | 2 | 0.98 | -8.65 | 75 | 2 | 0 | 0.8 | -8 | 25 | 0 |
| 7 | 0 | 0.984 | -7.58 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 2 | 1.005 | -4.45 | 150 | 22 | 450 | 62.1 | -140 | 200 | 0 |
| 9 | 2 | 0.98 | -9.56 | 121 | 26 | 0 | 2.2 | -3 | 9 | 0 |
| 10 | 0 | 0.986 | -11.43 | 5 | 2 | 0 | 0 | 0 | 0 | 0 |
| 11 | 0 | 0.974 | -10.17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 2 | 1.015 | -10.46 | 377 | 24 | 310 | 128.5 | -150 | 155 | 0 |
| 13 | 0 | 0.979 | -9.79 | 18 | 2.3 | 0 | 0 | 0 | 0 | 0 |
| 14 | 0 | 0.97 | -9.33 | 10.5 | 5.3 | 0 | 0 | 0 | 0 | 0 |
| 15 | 0 | 0.988 | -7.18 | 22 | 5 | 0 | 0 | 0 | 0 | 0 |
| 16 | 0 | 1.013 | -8.85 | 43 | 3 | 0 | 0 | 0 | 0 | 0 |
| 17 | 0 | 1.017 | -5.39 | 42 | 8 | 0 | 0 | 0 | 0 | 0 |
| 18 | 0 | 1.001 | -11.71 | 27.2 | 9.8 | 0 | 0 | 0 | 0 | 0 |
| 19 | 0 | 0.97 | -13.2 | 3.3 | 0.6 | 0 | 0 | 0 | 0 | 0 |
| 20 | 0 | 0.964 | -13.41 | 2.3 | 1 | 0 | 0 | 0 | 0 | 0 |
| 21 | 0 | 1.008 | -12.89 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | 0 | 1.01 | -12.84 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23 | 0 | 1.008 | -12.91 | 6.3 | 2.1 | 0 | 0 | 0 | 0 | 0 |
| 24 | 0 | 0.999 | -13.25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 25 | 0 | 0.982 | -18.13 | 6.3 | 3.2 | 0 | 0 | 0 | 0 | 0 |
| 26 | 0 | 0.959 | -12.95 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27 | 0 | 0.982 | -11.48 | 9.3 | 0.5 | 0 | 0 | 0 | 0 | 0 |
| 28 | 0 | 0.997 | -10.45 | 4.6 | 2.3 | 0 | 0 | 0 | 0 | 0 |
| 29 | 0 | 1.01 | -9.75 | 17 | 2.6 | 0 | 0 | 0 | 0 | 0 |
| 30 | 0 | 0.962 | -18.68 | 3.6 | 1.8 | 0 | 0 | 0 | 0 | 0 |
| 31 | 0 | 0.936 | -19.34 | 5.8 | 2.9 | 0 | 0 | 0 | 0 | 0 |
| 32 | 0 | 0.949 | -18.46 | 1.6 | 0.8 | 0 | 0 | 0 | 0 | 0 |
| 33 | 0 | 0.947 | -18.5 | 3.8 | 1.9 | 0 | 0 | 0 | 0 | 0 |
| 34 | 0 | 0.959 | -14.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 35 | 0 | 0.966 | -13.86 | 6 | 3 | 0 | 0 | 0 | 0 | 0 |
| 36 | 0 | 0.976 | -13.59 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 37 | 0 | 0.985 | -13.41 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 38 | 0 | 1.013 | -12.71 | 14 | 7 | 0 | 0 | 0 | 0 | 0 |
| 39 | 0 | 0.983 | -13.46 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 40 | 0 | 0.973 | -13.62 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 41 | 0 | 0.996 | -14.05 | 6.3 | 3 | 0 | 0 | 0 | 0 | 0 |
| 42 | 0 | 0.966 | -15.5 | 7.1 | 4.4 | 0 | 0 | 0 | 0 | 0 |
| 43 | 0 | 1.01 | -11.33 | 2 | 1 | 0 | 0 | 0 | 0 | 0 |
| 44 | 0 | 1.017 | -11.86 | 12 | 1.8 | 0 | 0 | 0 | 0 | 0 |
| 45 | 0 | 1.036 | -9.25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 46 | 0 | 1.05 | -11.89 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 47 | 0 | 1.033 | -12.49 | 29.7 | 11.6 | 0 | 0 | 0 | 0 | 0 |
| 48 | 0 | 1.027 | -12.59 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 49 | 0 | 1.036 | -12.92 | 18 | 8.5 | 0 | 0 | 0 | 0 | 0 |
| 50 | 0 | 1.023 | -13.39 | 21 | 10.5 | 0 | 0 | 0 | 0 | 0 |
| 51 | 0 | 1.052 | -12.52 | 18 | 5.3 | 0 | 0 | 0 | 0 | 0 |
| 52 | 0 | 0.98 | -11.47 | 4.9 | 2.2 | 0 | 0 | 0 | 0 | 0 |
| 53 | 0 | 0.971 | -12.23 | 20 | 10 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 54 | 0 | 0.996 | -11.69 | 4.1 | 1.4 | 0 | 0 | 0 | 0 | 0 |
| 55 | 0 | 1.031 | -10.78 | 6.8 | 3.4 | 0 | 0 | 0 | 0 | 0 |
| 56 | 0 | 0.968 | -16.04 | 7.6 | 2.2 | 0 | 0 | 0 | 0 | 0 |
| 57 | 0 | 0.965 | -16.56 | 6.7 | 2 | 0 | 0 | 0 | 0 | 0 |
| 58 | 2 | 1.279117 | 0 | 0 | 0 | 15 | 25.1 | 0 | 0 | 0 |

## Conclusion and future direction

The simulated DG are assumed to be set up at extraordinary buses and the entire device power loss turned into received in each case. It is observed from this discern that overall feeder strength loss reaches a minimal price while the DG is optimally located. The theoretical most effective role to vicinity the DG is found and the technology with admire to call for. The position along with this distance from the quit of feeder and different parameters are discover using ACO.

- The ACO based totally most fantastic DG parameters estimator is designed the makes use of of MATLAB programming algorithm.
- It has been proved that this optimization set of rules is pretty effectives for hastily locating the changes required in insertion of greater DG's location, voltages and electricity rankings in each the simulated and real-international electricity device scenarios taken into consideration.
- This has vast implications for electricity application intervention strategies.
- In future an approach can be proposed which can be primarily based on not iterative algorithms, like energy waft packages. Therefore, there may be no convergence issues concerned, and consequences could be received in no time.
- A collection of simulation studies can be carried out to verify the validity of the proposed strategies, and effects may be discovered on proposed strategies in future.
- In exercise there are other constraints which may affect the DG placement. Nevertheless, methodologies presented in this paintings can be powerful, instructive, and beneficial that can also be taken into consideration for the machine designers in choosing right web sites to area DGs.

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