



# **Optimal Design of Multitype DG Resources Using Particle Swarm Optimization**

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**ABSTRACT:** Increased interest in application of green technology and shortage of distributed current carrying capabilities has led to use of Distributed Generation (DG) Systems. The estimated use of DG in the future requires the distribution system engineers to properly take into account its impact in the system planning. Hence, optimal location and sizing of DG in distribution networks is drawing much attention in electric power utilities. Optimal allocation of different types of renewable DG units in the distribution system is used to minimize energy loss. Proper location of DG units in power systems is used to maximize the potential benefits and reduce impact on the power system. Heuristic optimization techniques like Particle Swarm Optimization (PSO), is used as a solver tool to minimize the power loss by changing sitting and varying sizes of DG. The simulation will be carried out on standard rural distribution networks viz, 15-bus and 69-bus distribution systems.

**KEYWORDS:** Particle Swarm Optimization(PSO), Distributed generation(DG), Optimum Location, Optimum Size, Power loss.

## **I.INTRODUCTION**

The rapid growth in electricity demand is to encourage the widespread service of Distributed Generation(DG) as there continues interest in operating it in parallel with a utility distribution system[1].The newly introduced distributed or decentralized generation units connected to local distribution systems are not dispatchable by central operator, but they can have a significant impact on the power flow, voltage profile, stability, continuity, short circuit level and quality of power supply for customers and electricity suppliers. It is widely accepted that renewable energy sources are the key to a sustainable energy supply infrastructure since they are both inexhaustible and non-polluting. DG has a lot of features which makes it attractive and offer good immediate solution to the ever growing power demand [2-3]. Many research outputs have shown that improper allocation and sizing can result in high power losses and can jeopardise the system performance or results in instability [4]. The effect of power loss has become a major problem because it reduces the efficiency of power transfer and deteriorates the voltage profile. The minimization of power loss in the distribution network is gaining much significance when compared to the transmission system. The optimal placement and sizing of DG units in the existing grid system attempt to reduce the power loss to a considerable extent. Various optimization techniques should be employed for allowing the best allocation of the DG.

## **II.LITERATURE REVIEW**

A "2/3 rule" is presented in [5] to place DG on a radial feeder with uniformly distributed load, and it is recommended to install DG of approximately 2/3 capacity of the incoming generation at approximately 2/3 of the length of line from the sending end. This rule is simple and easy to use, but it cannot be useful directly to a feeder with other types of load distribution. In [6] the authors for the case of multiple DG allocation with the aim of minimizing active power losses in radial Distribution network using Genetic algorithm. The technological benefits from consumer point were assessed however, in the analysis only active power supply was considered. In the same way [7] proposes sizing using a new optimization technique called Artificial Bee Colony (ABC) algorithm to optimally size and allocate the DG for real power minimization. Even though the method has the advantage of controlled parameters, but it involves random process during initialization of the population and can give inconsistent results many times. Use of loss formula was employed by [8] to optimally size and allocate single DG by calculating the bus admittance. Such technique lack robustness as system complexity increases. In the same direction, the authors in [9] formulated a multi-objective function that consists of positive impacts of DG such as voltage profile improvements as well as the negative ones such as increased system loss and short-circuit level. This phenomenon can arise due to the wrong sited of DG locations.



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The use of continuation power flow was proposed by [10] so as to determine the most sensitive buses to voltage collapse and used as the applicant for DG placement. Many other methods uses heuristic techniques for DG placement in Distribution networks among which one of the approach is Tabu search [11], for optimizing the problem which is based on the concept of Pareto Optimality. In [12], optimal DG placement and reclosures based on reliability of the network was done by using Ant Colony Search (ACS) algorithm.

In this paper, the optimal placement problem has been solved using PSO by taking the objective function as exact loss formula. This paper presents a simple PSO for optimal placement of DG in power systems using loss reduction criterion. The placement of DG is analysed and the optimal location of bus for adding DG in distributed load patterns is chosen. The Extensive simulations s carried out to show the effectiveness of the proposed methodology in determining the optimal bus for the placement of DG and reducing the power losses in the system. The proposed method is tested in standard IEEE distribution networks. After identifying the optimal design of DG, the voltage improvement and power loss reduction of the distribution network is analysed.

## III.DISTRIBUTED GENERATION

Distributed generation is an electric power source connected directly to the distribution network or customer side of the meter. The definition of distributed generation takes different forms in different markets and countries and is defined differently by different agencies. International Energy Agency (IEA) defines Distributed generation as generating plant serving a customer on-site or providing support to a distribution network, connected to the grid at distribution level voltages. CIGRE defines DG as the generation, which has the following characteristics: It is not centrally planned; It is not centrally dispatched at present; It is usually connected to the distribution network; It is smaller than 50–100MW. Distributed generation also called On-site generation, dispersed generation, embedded generation, decentralized generation, decentralized energy or distribution energy. The major benefits of distributed generation can be divided into two categories: economic and operational[17]. In general DG means small scale generation.

Many DG technologies are accessible but few are still in research and enlargement stage. The major relevance of DG in deregulated environment lies in the form of ancillary services. DG also benefits like plummeting energy costs and less exposure to price volatility. In this study, DGs capable of supplying both real and reactive power are considered. Different types of the DG's can be characterized as [13]:

Type I: DG capable of injecting real power only, like photovoltaic, fuel cells etc. is the good examples of type-I DG. Type II: DG capable of injecting reactive power only to improve the voltage profile e.g. kvar compensator, synchronous compensator, capacitors etc. Type III: DG capable of injecting both real and reactive power, e.g. synchronous machines. Type IV: DG capable of injecting real but consuming reactive power, e.g. induction generators used in the wind farms. Most of the approaches presented so far to formulate the optimal placement problem of DG are considering only the type-I DGs. In the present work type-I, type-II and type-III DG's are considered for optimal placement and sizing problem. Optimal placement problem has been solved using PSO algorithm with the exact loss formula as objective function.

## IV.PROBLEM FORMULATION

The optimal sizing and placement of DG results in minimum loss in the distribution system[15]. The majority of the DGP objectives is to minimize MVA loss in the distribution system is given by equation(1).

$$\text{Minimize } S_l = \sqrt{P_l^2 + Q_l^2} \quad (1)$$

considering N bus distribution systems, the total real and reactive power loss minimization may be formulated as given below equations(2) and (3):

$$\text{Minimize } P_l = \sum_i^N \sum_j^N [\alpha_{ij}(P_i P_j + Q_i Q_j) + \beta_{ij}(Q_i P_j - P_i Q_j)] \quad (2)$$

$$\text{Minimize } Q_l = \sum_i^N \sum_j^N [\gamma_{ij}(P_i P_j + Q_i Q_j) + \xi_{ij}(Q_i P_j - P_i Q_j)] \quad (3)$$

where



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$$\alpha_{ij} = \frac{R_{ij}}{V_i V_j} \cos(\delta_i - \delta_j)$$

$$\beta_{ij} = \frac{R_{ij}}{V_i V_j} \sin(\delta_i - \delta_j)$$

$$\gamma_{ij} = \frac{X_{ij}}{V_i V_j} \cos(\delta_i - \delta_j)$$

$$\xi_{ij} = \frac{X_{ij}}{V_i V_j} \sin(\delta_i - \delta_j)$$

and

$$Z_{ij} = R_{ij} + jX_{ij}$$

where

$Z_{ij}$  is the impedance of the line between bus i and bus j;

$R_{ij}$  is the resistance of the line between bus i and bus j;

$X_{ij}$  is the reactance of the line between bus i and bus j;

$V_i$  is the voltage magnitude at bus i ;

$V_j$  is the voltage magnitude at bus j ;

$\delta_i$  is the voltage angle at bus i ;

$\delta_j$  is the voltage angle at bus j;

$P_i$  and  $Q_i$  is the active and reactive power injection at bus i;

$P_j$  and  $Q_j$  is the active and reactive power injection at bus j;

### Constraints:

Another significant part of the optimization model that needs to be defined is the constraints. There are two types of constraints they are

1. Equality Constraints
2. Inequality Constraints

#### 1) Equality Constraints

These constraints are related to the nonlinear power flow equations.

$$P_i = P_{DG_i} - P_{D_i} \tag{4}$$

$$Q_i = Q_{DG_i} - Q_{D_i} \tag{5}$$

where

$P_{DG_i}$  and  $Q_{DG_i}$  are real and reactive power injection from DG is placed at node i .

$P_{D_i}$  and  $Q_{D_i}$  are the load demand at node i .

#### 2).Inequality constraint:

The Inequality constraints are those associated with bus voltages and DG to be installed.

##### (a)Bus Voltage Limit:

The bus voltage magnitudes are to be kept within acceptable operating limits throughout the optimization process.

$$V_{min} \leq V_i \leq V_{max} \tag{6}$$

where

$V_{min}$  is Lower bound of bus voltage limits.

$V_i$  is RMS value of the bus voltage.

$V_{max}$  is Upper bound of bus voltage limits.

##### (b)Number and sizes of DGs:

These are constraints related with the DG and themselves. DGs that are commercially available come in discrete sizes.

$$P_{inject} - DG_i \leq -L_{Po}$$

$$Q_{inject} - DG_i \leq -L_{Qo}$$

where L=1,2,..n;  $P_o$ ,  $Q_o$  is smallest DG size available



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## V.PARTICLE SWARM OPTIMIZATION

### A. OVERVIEW OF PSO

Particle swarm optimization is a stochastic, population-based evolutionary computer algorithm for problem solving. It is a kind of swarm intelligence that is based on social-psychological principles and provides insights into social behaviour, as well as contributing to engineering applications. The particle swarm optimization algorithm was first described in 1995 by JAMES KENNEDY and RUSSELL C.EBERHART. For a given problem, to evaluate a proposed solution to it exists in the form of a fitness function. A communication structure or social network is also defined; assigning neighbours for each individual defined as random guesses at the problem solutions is initialized. These individuals are candidate solutions. They are also known as the particles, hence the name particle swarm. An iterative process to improve these candidate solutions is set in motion. PSO is one of the most recent developments in the category of combinatorial meta heuristic optimizations. [14]The particles iteratively evaluate the fitness of the candidate solutions and remember the location where they had their best success. The individuals best solution is called the particle best or local best. Each particle makes this information available to their neighbours. The particle velocity and position update equations in the simplest form that govern the PSO are given by equations (7) and (8)

$$v_i^{k+1} = w \cdot v_i^k + C_1 R_1 (Pbest_i^k - S_i^k) + C_2 R_2 (Gbest_i^k - S_i^k) \quad (7)$$

$$S_i^{k+1} = S_i^k + v_i^{k+1} ; i = 1, 2, \dots, N \quad (8)$$

Where

N represents number of particle in the swarm,

i denotes the  $i^{th}$  particle in the swarm,

$S_i^k$  is the  $i^{th}$  particle position in iteration k,

$v_i^{k+1}$  is the velocity of the particle j in  $k+1^{th}$  iteration,

$Pbest_i$  is the best position of  $i^{th}$  particle,

$Gbest$  is the best position among all particles in the swarm,

w is the inertia weight,

$C_1$  and  $C_2$  are cognitive parameter and social parameter,

$R_1$  and  $R_2$  are the random numbers,

k is an iteration number,

$k_{max}$  is the maximum iteration .

Acceleration constant  $C_1$  pulls each particle towards local best position whereas constant  $C_2$  pulls the particle towards global best position. Suitable selection of weight factor w helps in quick convergence. In this study, linearly decreasing weight w is considered instead of constant weight and it is represented by the following equation (9).

$$W = w_{max} - ((w_{max} - w_{min}) / k_{max}) * k \quad (9)$$

Each of the three terms of the velocity update equation have different roles in the PSO algorithm and each particle maintains its position, composed of the candidate solution and its evaluated fitness, and its velocity. The best fitness value it has achieved thus far during the operation of algorithm, referred to as the individual best fitness, and the candidate solution that achieved this fitness, referred to as the individual best position. Finally, the PSO algorithm maintains the best fitness value achieved among all particles in the swarm, called the global best fitness, and the candidate solution that achieved this fitness, called the global best position or global best candidate solution.

The PSO algorithm consists of just three steps, which are repeated until some stopping condition is met:

1. Evaluate the fitness of each particle
2. Update individual and global best fitness and positions
3. Update velocity and position of each particle.

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## B. BASIC MODEL OF PSO

In a PSO method, all particles are initiated randomly and evaluated to compute fitness together with finding the personal best (best value of each particle) and global best (best value of particle in the entire swarm). After that a loop starts to find an optimum solution. In the loop, first the particle's velocity is updated by the personal and global bests, and then each particle's position is updated by the current velocity. The loop is ended with a stopping criterion predetermined in advance.

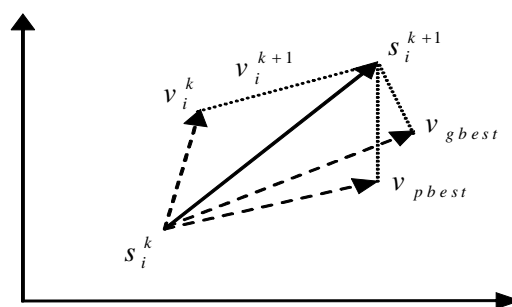


Figure 5.1. Model of PSO

$V_i^K$  the current velocity of particle  $i$  at iteration  $k$ ,

$V_i^{K+1}$  the modified velocity of particle  $i$ ,

$S_i^K$  the current position of particle  $i$  at iteration  $k$ ,

$S_i^{K+1}$  the modified position of particle  $i$ ,

PSO consists of a group (swarm) of individuals (particles) moving in the search space looking for the best solution. Each particle is represented by a vector  $s$  of length  $n$  indicating the position and has velocity vector  $v$  used to update the current position which adjusts its flying according to its own flying experience as well as the flying experience of other particles. Each particle keeps track of its coordinates in the solution space which are associated with the best solution (fitness) that has achieved so far by that particle. This value is called personal best,  $pbest$ . Another best value that is tracked by the PSO is the best value obtained so far by any particle in the neighbourhood of that particle. This value is called  $gbest$ . The basic concept of PSO lies in accelerating each particle toward its  $pbest$  and the  $gbest$  locations, with a random weighted acceleration at each time step as shown in Fig.5.1.

## C. PSO ALGORITHM

The PSO based approach for solving optimal placement of DG for total power loss takes the following steps:

- Step 1 Input system line, bus data and bus voltage limits, DG real and reactive power generation limits.
- Step 2 Calculate the bus voltage and MVA loss using base case load flow .
- Step 3 Define the control variables(real power sizing, reactive power sizing and location of DG) within their permissible range and randomly initialize a population of particles with position  $S_i$  and velocities  $V_i$  of the  $i^{\text{th}}$  particle.
- step 4 Set the parameters of PSO,  $C_1 = C_2 = 2$ ,  $W_{\max} = 0.9$ ,  $W_{\min} = 0.4$ .
- Step 5 For each particle, run load flow program and obtain bus voltage magnitude and angle.
- Step 6 Calculate fitness function of each particle using equation(1).



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- Step 7* Compare the current position with particle's previous best experience, pbest, in terms of fitness value and hence update pbest for each particle in the population.
- Step 8* After updating the pbest, choose the best value among all the particles in pbest and call it as Global best, gbest.
- Step 9* Set iteration =iteration+1.
- Step 10* Calculate velocity of each particle and update if constraints limit get violated.
- Step 11* Then calculate new position of each particle.
- Step 12* For each particle run load flow program and calculate the fitness function.
- Step 13* Then go to step 6 until the stopping criterion or maximum iterations is reached.
- Step 14* Finally the optimal DG sizing & placement can be evaluated by tracing the gbest particle and optimized (minimized) value of MVA loss is obtained using fitness function.

## VI. TEST SYSTEMS AND RESULTS

The program code for the optimal placement and sizing of DG units using PSO is developed in MATLAB environment. The proposed methods have been developed and simulated in MATLAB environment using Matlab 7.9 version. The suitable solution techniques for optimal placing of DG units and real power loss minimization is designed on PC with 2.6GHz core i5 CPU and 6 GB RAM.

### A. TEST SYSTEM

The proposed methodology was tested on a distribution system consisting of 15 bus and 69 bus distribution systems. In this simulation two different test systems are used to legalize the result for optimal sizing, placement and power loss reduction. The first test system is 15 bus system with total load of 1.23 MW and 1.25 MVar. The second test system is 69 bus system with total load of 3.80 MW and 2.69 MVar[16].

#### A.1. Test system-15 bus distribution system

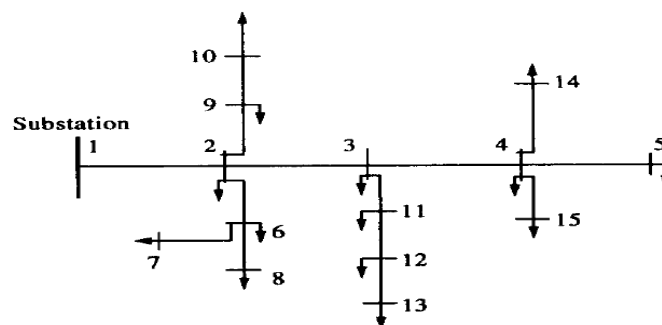


Figure 6.1. Single line diagram of 15 bus distribution test system

The first test system is 15 bus distribution system with total load of 1.23 MW and 1.25 MVar. The one line diagram for the 15-bus distribution system is shown in Figure 6.1. The bus data and line data for 15 bus system is given in [18].

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## A.2. Test system-69 bus distribution system



Figure 6.2. Single line diagram of 69 bus distribution test system

The second test system is 69 bus distribution system with total load of 3.80 MW and 2.69 MVar. The one line diagram for the 69-bus distribution system is shown in Figure 6.2 and the bus data and line data for 69 bus system is given in [19].

## B. RESULTS AND DISCUSSIONS

By applying PSO, the algorithm discussed in section 5.3, the total MVA loss can be minimized and optimal sizes of DG units are calculated at each and every bus. The proposed methods have been developed to calculate the optimum sizes of DG at various buses and MVA losses with DG at different locations to identify the best locations. Thus, power loss is found to be minimized by the optimal placement of DG. The system voltage profile is also studied after identifying the optimal DG placement.

### B.1. Results of 15 bus distribution system

The sized DG units are placed at each bus location and the corresponding average MVA loss and average voltage of the system are calculated. After the placement of DG unit at optimally selected bus, the real power loss in per unit value are calculated as shown in Table 6.1 below. It is observed from Table 6.1 that by installing the DG unit of appropriate size gives minimum real power loss, that is before placement of DG average Ploss is found to be 0.0597 (p.u) and after placement of DG it is found to be 0.0257 (p.u). By using PSO, the average real power loss reduction for 15 bus system is reduced to 56.95%. The percentage of real power loss reduction is calculated by comparing the results of average Ploss of with DG and without DG placement.

Table 6.1. AVERAGE REAL POWER LOSS REDUCTION WITHOUT AND WITH DG PLACEMENT FOR 15 BUS SYSTEM USING PSO

Test System	DG location	DG real power size(MW)	Average Ploss without DG placement(p.u)	Average Ploss with DG placement(p.u)	% Ploss reduction
15 bus system	11	0.5	0.0597	0.0257	56.95

And after the placement of DG unit at optimally selected bus, the reactive power loss in per unit value are calculated and it is shown in Table 6.2 below. Before placement of DG the average reactive power loss is 0.0553 (p.u) and after

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the placement of DG average reactive power loss is 0.0215 (p.u). The reactive power loss reduction for 15 bus system is 61.12%. The percentage of reactive power loss reduction is calculated by comparing the results of average Qloss of with DG and without DG placement.

Table 6.2. AVERAGE REACTIVE POWER LOSS REDUCTION WITHOUT AND WITH DG PLACEMENT FOR 15 BUS SYSTEM USING PSO

Test System	DG location	DG reactive power size(MVAr)	Average Qloss without DG placement(p.u)	Average Qloss with DG placement(p.u)	% Qloss reduction
15 bus system	15	0.5	0.0553	0.0215	61.12

With DG the total losses can be drastically reduced while satisfying the voltage constraints. Table 6.3 shows average voltage magnitude before and after the placement of DG that is without DG placement average voltage is found to be 0.9581 (p.u) and after placement of DG average voltage for 15 bus system is 0.9772 (p.u). It is also seen that DG installation at the optimal locations improves voltage profile and at the same time reduces total MVA losses of the network. After the placement of DG unit at selected optimal bus, the average voltage in per unit value is calculated based on the voltage magnitude at each bus and is shown in Table.6.3 below. The voltage improvement after the placement of DG is found to be 1.9935 percentage.

Table 6.3. VOLTAGE PROFILE IMPROVEMENT FOR 15 BUS SYTEM

Test System	Average Voltage without DG placement(p.u)	Average Voltage with DG placement(p.u)	% of Voltage improvement
15 bus system	0.9581	0.9772	1.9935

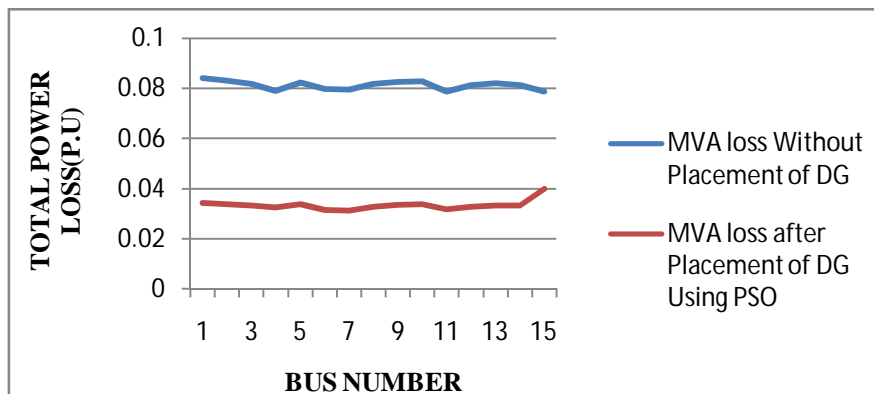


Fig.6.3 MVA Loss with and without placement of DG for 15 bus distribution system

Figure.6.3. shows the per unit value of MVA loss at each bus with and without placement of DG using PSO for IEEE 15 bus system. Without DG Placement the total Power loss is 122.99 MVA and after placement of DG total MVA loss is found to be 50.29 MVA.



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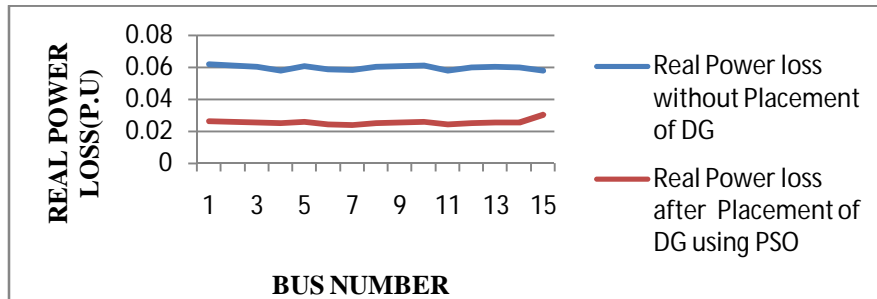


Fig.6.4.Real Power Loss with and without placement of DG for 15 bus distribution system

The total real power loss with the optimal DG placement at various buses is shown in Fig 6.4. Without DG Placement the total real loss is 544.9 MW and after placement of DG real power loss is 38.12 MW.

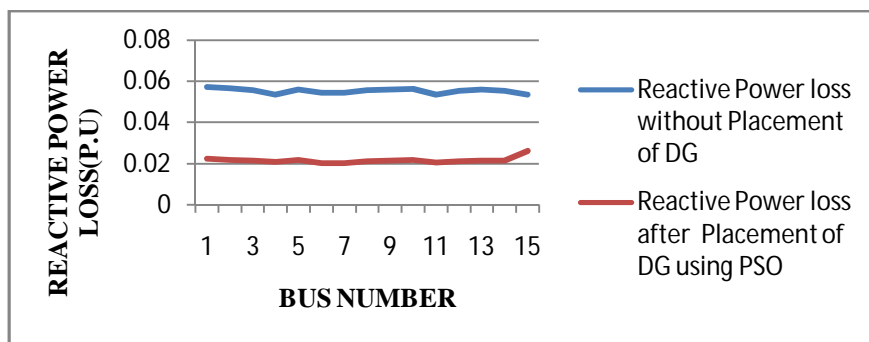


Fig.6.5.Reactive Power Loss with and without placement of DG for 15 bus distribution system

The total reactive power losses with the optimal DG placement at various buses is shown in Fig 6.5. Without DG Placement the reactive power loss is 48.84 MVar and after placement of DG reactive power loss is 32.30 MVar.

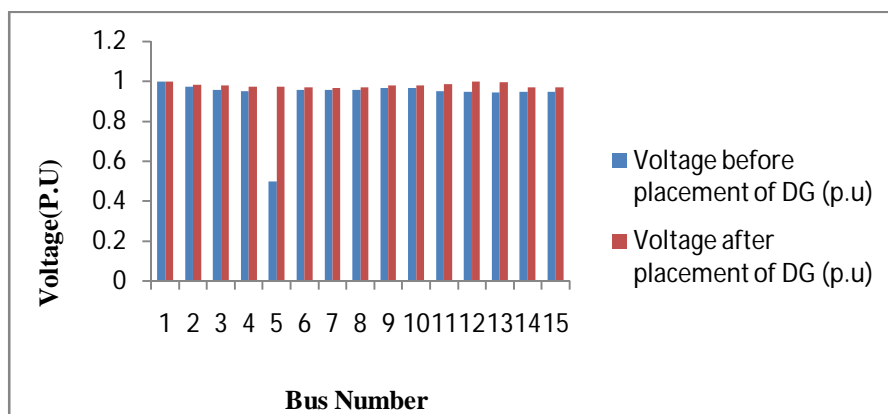


Fig.6.6.Voltage at all buses with DG and without DG for 15 bus system

The optimization method can also be used to determine the locations and sizes of the DG units, so as to achieve the target of improving voltage profile in the distribution systems. The bus voltage magnitude at each bus by placing DG unit is compared with the case of without DG placement as shown in Figure 6.6. It is seen that the bus voltage profile is improved while placing DG unit at optimal location . Further, it has been observed that optimal DG placement also



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helps to avoid the violation of the bus voltage limits on the system. Thus, by reducing the power losses, the overall voltage can be improved on the system after the placement of DG.

## B.2. Results of 69 bus distribution system

An optimal sizing of DG unit at each bus except reference bus is calculated and after the placement of DG unit at optimally selected bus, the real power loss in per unit value are calculated is shown in below Table.6.4. It is observed from Table 6.4 that by installing the DG unit of appropriate size gives minimum real power loss that is before placement of DG average real power loss is found to be 0.3162 (p.u) and after placement of DG the average real power loss is 0.2244 (p.u). By using PSO the percentage of average real power loss reduction for 69 bus system is 29.032. The percentage of real power loss reduction is calculated by comparing the results of average Ploss of with DG and without DG placement.

Table 6.4. AVERAGE REAL POWER LOSS REDUCTION WITHOUT AND WITH DG PLACEMENT FOR 69 BUS SYSTEM USING PSO

Test System	DG location	DG real power size(MW)	Average Ploss without DG placement	Average Ploss with DG placement	% Ploss reduction
69 bus system	64	0.25	0.3162	0.2244	29.032

And after the placement of DG unit at optimally selected bus, the average reactive power loss in per unit value are calculated and it is shown in below Table.6.5. Before placement of DG the average reactive power loss is found to be 0.1431 (p.u) and after the placement of DG the average reactive power loss is 0.1040 (p.u). The average reactive power loss reduction for 69 bus system is 27.32% . The percentage of reactive power loss reduction is calculated by comparing the results of average Qloss of with DG and without DG placement.

Table 6.5. AVERAGE REACTIVE POWER LOSS REDUCTION WITHOUT AND WITH DG PLACEMENT FOR 15 BUS SYSTEM USING PSO

Test System	DG location	DG reactive power size(MVAr)	Average Qloss without DG placement	Average Qloss with DG placement	% Qloss reduction
69 bus system	64	0.25	0.1431	0.1040	27.32

DG installation at the optimal locations improves voltage profile and at the same time reduces total MVA losses of the network. The average Voltage without DG placement is 0.9637 (p.u) and after placement of DG, the average voltage for 69 bus system is 0.9681(p.u). The sized DG units are placed at each bus location and the corresponding average MVA loss and average voltage of the system are calculated. After the placement of DG unit at each bus, the average voltage in per unit value are calculated as shown in Table.6.6. below. The percentage of voltage improvement after the placement of DG is found to be 0.4544.

Table 6.6. VOLTAGE PROFILE IMPROVEMENT FOR 69 BUS SYSTEM

Test System	Average Voltage without DG placement(p.u)	Average Voltage with DG placement(p.u)	% of Voltage improvement
69 bus system	0.9637	0.9681	0.4544

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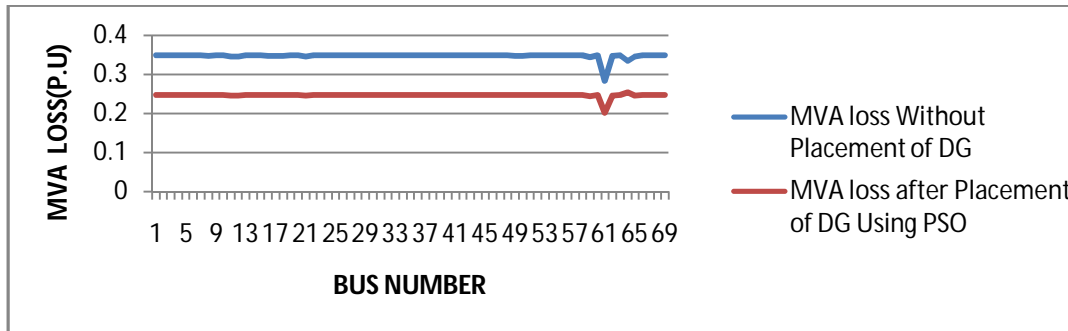


Fig.6.7.MVA Loss with and without placement of DG for 69 bus distribution system

Figure.6.7 shows the representation of MVA loss with and without placement of DG using PSO for IEEE 69 bus system. Without DG Placement the total power loss is 2394.83 MVA and after placement of DG total MVA loss is 1706.44 MVA.

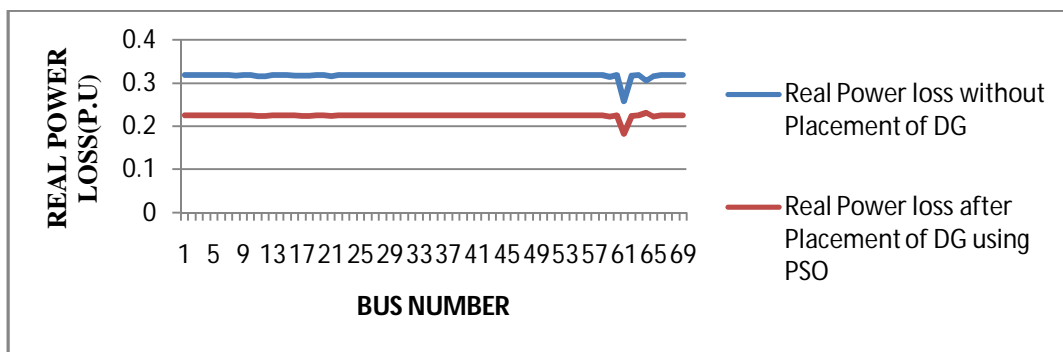


Fig.6.8.Real Power Loss with and without placement of DG for 69 bus distribution system

The total real power losses with the optimal DG placement at various buses for 69 bus system is shown in Fig 6.8 .Thus with the placement of DG the total real power losses can be drastically reduced while satisfying the constraints.

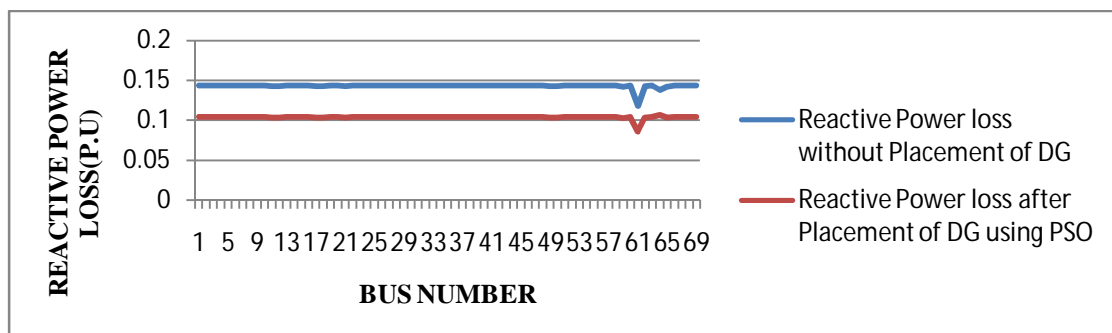


Fig.6.9.Reactive Power Loss with and without placement of DG for 69 bus distribution system

The total reactive power losses with the optimal DG placement for 69 bus system is shown Fig 6.9 and it is observed that losses are reduced drastically for 69 bus system as seen in 15 bus system. The optimum placement of DG is bus 64 where is the minimum reactive power losses. It is seen that the total reactive power losses reduces significantly by adding the DG in the distribution networks.

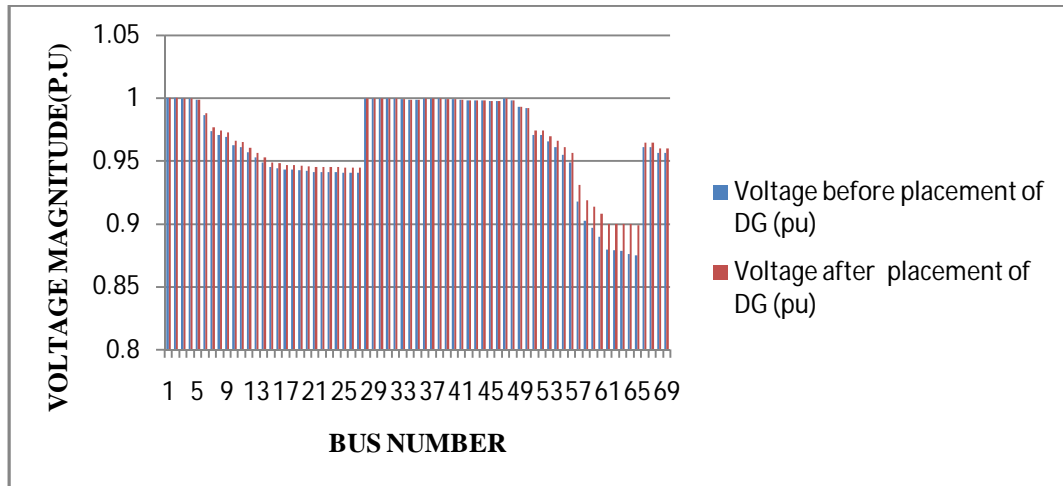


Fig.6.10.Voltage at all buses with DG and without DG for 69 bus system

The bus voltage magnitude at each bus by placing DG unit is compared with the case of without DG placement as shown in Figure 6.10. and it illustrates that, adding DG to distribution system improves the profile of voltages in all buses. The average voltage before placement of DG is 0.9637 (p.u) and after placement of DG the average voltage is 0.9681 (p.u) for 69 bus distribution system.

## VII.CONCLUSIONS

The improvement on the system depends largely on where the DG is located. The effect of power loss has become a major problem because it reduces the efficiency of power transfer and deteriorates the voltage profile. The minimization of power loss in the distribution network is gaining much significance when compared to the transmission system. The optimal placement and sizing of DG units using PSO algorithm in the existing system attempt to reduce the real and reactive power loss to a considerable extent. The methodology has been tested on standard IEEE rural distribution systems viz., 15 and 69 bus test systems. Installing DG resources at critical bus has proved to improve the system performance most effectively. Results shows that the locations and sizing of distributed generations are decisive factors in reducing MVA losses in the system. Further work will focus on cost minimization of DG units along with loss minimization subject to system operating constraints.

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