Distribution System Performance Enhancement through Optimal DG Placement using PSO

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Abstract— Optimal allocation of distributed generators (DG) plays a significant role in improving the performance of the radial distribution system. The positive and negative impact of the distributed generators will depend on the optimal location and size of distributed generators. Therefore, this paper focuses on selecting optimal size and location for distributed generator in the radial distribution systems (RDS) to minimize power losses and improve voltage profile. Backward Forward Sweep methodology for the load flow analysis of the distribution system is used to determine the power losses in the system and Particle Swarm Optimization (PSO) is used to solve the optimization problem. A 33-bus system has been taken as the test system.

Key words: Distributed Generators (DG), Particle Swarm Optimization (PSO), Radial Distribution System (RDS)

I. INTRODUCTION

Electrical distribution network systems include distribution feeder, which are arranged in mesh or radial pattern. The radial distribution system has high resistance to reactance ratio. Because of its high resistance to reactance ratio there will be increase in power losses and reduction in the magnitude of bus voltage. Therefore, to increase the performance of distribution system, introduction of DG's takes place in the networ0k [1]-[2].

Distributed Generation refers to any electric power production technology that is integrated within distribution systems or on the customer site of the meter. Optimal allocation of distributed generators helps in minimization of power losses and improvement of voltage stability in power systems. To achieve the most from DG installation, it has to be optimally placed and sized. Improper installation of DG may degrade the performance of the distribution system. This has made the problem of optimal allocation of distributed generation to be an interesting research topic for many researchers.

There are various methods used for solving the problem of DG allocation for reduction of power losses in the distribution system. These methods are: Analytical [3], Improved Analytical (IA) [4], Dynamic Programming [5], and Mixed Integer Linear Programming (MILP) [6]. These methods are used to solve only linear optimization problems. But the DG location and sizing problem is not a linear optimization problem, it is a discrete nonlinear optimization problem. Because of nonlinear optimization problem, these techniques are not that much effective in solving optimal allocation problem in the distribution system. So, it is essential to consider search algorithms importance in solving above mentioned problem. Recently many search algorithms, i.e. Genetic Algorithm (GA) [7], Particle Swarm Optimization (PSO) [8], Combined Genetic and Particle Swarm Optimization [9], Cuckoo search algorithm (CSA) [10], Tabu Search (TS) [11], Simulated Annealing (SA) [12], Artificial Bee Colony (ABC) [13] are used to solve DG allocation problem effectively with reduced power losses as a main objective.

To select appropriate location and to calculate DG size for minimum real power losses Naresh Acharya et al presented a heuristic method in [14]. But more computational efforts are needed to solve the problem. At each bus the optimal value of DG is calculated for minimum system losses. By placing the calculated DG size for each and every bus of the system, corresponding system losses are calculated and compared to decide the appropriate location.

PSO was introduced by Kennedy, J. and R. Eberhart [15]. AlRashidi M.R. and El Hawary M.E. [16] have noted the advantages of PSO technique.

This paper is aimed at reducing power loss and improving voltage profile of distribution systems using DG sources. Optimal placement of DG is obtained by considering the voltage profile. Here Particle Swarm Optimization (PSO) is employed to obtain the optimal sizing of DG. The analysis has been carried out for IEEE 33 radial bus test system.

II. PROBLEM FORMULATION

The main objective of this paper is to obtain power flow solution of IEEE 33 bus radial distribution system using backward and forward sweep method. From the load flow analysis most sensitive bus is identified for DG placement. Particle Swarm Optimization (PSO) is used to find the optimal size of DG. The purpose of DG placement is to minimize the total active power loss and improving the voltage profile.

III. PROPOSED WORK

A. Load Flow Analysis

The real power loss reduction in a distribution system is required for efficient power system operation. The loss I^2R loss (P_{Loss}) in a distribution system having n number of branches is given by equation (1)

$$P_{loss} = \sum_{i=1}^{n} I(i)^2 R(i) \quad (1)$$

Where I(i) is the magnitude of the branch current and R(i) is the resistance of the i^{th} branch respectively. The branch current can be obtained from the load flow solution [17].

B. Sensitive Node Identification

From Load Flow solution obtained by using Backward and Forward Sweep Method, voltage magnitude is computed at each and every bus of the system. The bus having minimum voltage magnitude is considered to be the most sensitive node for the placement of DG.

C. Particle Swarm Optimization (PSO)

For finding the best solution for any given circumstances, the optimization technique is used. For example, if a company required to improve its rating, technological and managerial plans have to be taken many times. Here, maximization of profits and minimization of the spending efforts are the basic aim of the plans. Optimization is referred to as both minimizing and maximizing the tasks. Due to this reason, optimization became very important in many fields.

Basically, in order to solve the problems of optimization, PSO technique is introduced by Kennedy and Eberhart in 1995. This technique is inspired by the animal's activity. In PSO, the meaning of swarm is population; particle represents each member of the population. Each particle searches through the entire space by randomly moving in different directions and remembers the previous best solutions of that particle and also positions of its neighbor particles. Particles of a swarm adapt their position and velocity dynamically by communicating best positions of all the particles with each other. The particle's position and velocity can be updated by eq. (2) and eq. (3):

$$V_i^{t+1} = wV_i^t + c_1 r_1 (pbest - x_i^t) + c_2 r_2 (gbest - x_i^t) \quad (2)$$

$$x_i^t + 1 = x_i^t + V_i^{t+1} \quad (3)$$

Where

- x^t is current searching point.
- X^{t+1} is modified searching point.
- V^t is current velocity.
- V^{t+1} is modified velocity.
- pbest is best position of particle.
- gbest is best position of swarm.
- c_1 and c_2 are weighing co-efficient.
- r_1 and r_2 are random numbers.

In this way, all the particles in the swarm try to shift in the direction of better positions until the swarm reaches an optimal solution. PSO technique is becoming very popular. Because of its easy implementation and its ability to obtain fast convergence and also it uses only basic mathematics and it does not involve any derivative or gradient information.

1) Advantages & Disadvantages of PSO

PSO technique is an effective technique for solving the non-linear optimization problems. There are some advantages and disadvantages of PSO as following:

a) Advantages of the PSO Algorithm

- PSO technique is a gradient-free technique.
- It has simple calculations.
- It is applied both in scientific research and engineering problems because of its easy implementation.
- Compared to other optimization techniques, this algorithm has less impact of parameters to the optimal solution as it has only less number of parameters.
- Optimum value can be obtained easily within short time.
- Compared to other optimization techniques, this algorithm has less dependence on set of initial values.
- Simple concept is involved here.

b) Disadvantages of the PSO Algorithm

- Here the speed and direction may be degraded as this technique suffers from partial optimism.
- Non-coordinate system exit problem may occur.

D. Implementation of PSO Algorithm to determine the. Size of DG Algorithm

The PSO-based approach for finding sizes of DGs at selected locations to minimize the real power loss is as follows:

Considering Objective Function:
f = Min (Total Real Power Loss)
Where the total real power loss is given by the expression:

$$P_{loss} = \sum_{i=1}^{n} I(i)^2 R(i)$$

1) Step 1. Choose the parameters that are to be optimized by using PSO. Here the parameters are real power that are injected through DG into distributed system i.e. size of DG in order to minimize the losses and improve voltage.
2) Step 2. Choose the size of swarm.
3) Step 3. Randomly generate the values for DG size.
4) Step 4. Run the load flow and obtain the voltage profile and losses of the system.
5) Step 5. The location of the DG to be placed is obtained by using voltage magnitude.
6) Step 6. Consider the fitness function as the real loss as we need to find the optimal DG size that minimize the losses.
7) Step 7. Randomly initialize the position and velocity of swarm.
8) Step 8. By placing different sizes of DG in the obtained location, compute and store the fitness function of all particles in the swarm.
9) Step 9. Consider the initial randomly generated sizes of DG as personal best (PBEST).
10) Step 10. Iterate through all the values of fitness function and the particle with minimum loss is considered as the global best (GBEST).
11) Step 11. Initialize the acceleration coefficients as c_1=2 and c_2=2.
12) Step 12. Initialize the loop and iteration count. For each particle calculate and update the velocity and position from (2) and (3).
13) Step 13. Run the load flow after placing DG and obtain the new fitness function for each particle. If the new fitness value for any particle is better than previous PBEST value then PBEST value for that particle is set to present fitness value. Similarly, GBEST value is identified from the latest PBEST values.
14) Step 14. If it reaches maximum iteration count then terminate the loop and plot the results. Otherwise increment the iteration count and go to step 12.
15) Step 15. GBEST value gives optimal the size of DG.

IV. RESULTS & DISCUSSION

The proposed method for the DG placement and sizing is demonstrated on IEEE 33 bus system. The Base voltage for this system is 12.66 kV. The single line diagram of 33-bus system is shown in Fig. 2.

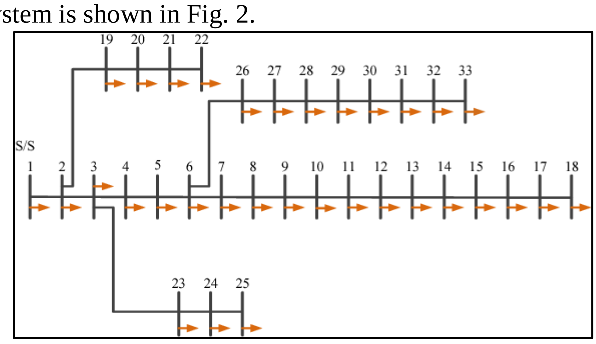

Fig. 2: Single Line Diagram of 33 Bus System

It has 33 buses and 32 branches. The total real and reactive power loads of the system are 3715 kW and 2300 kVAr. Load flow results are shown in Table 1.

Bus System	Real Power Loss (kW)	Reactive Power Loss (kVRr)
33	208.281	139.303

Table 1: Load flow Results

The optimal location for placement of DG is identified based on minimum voltage magnitude.

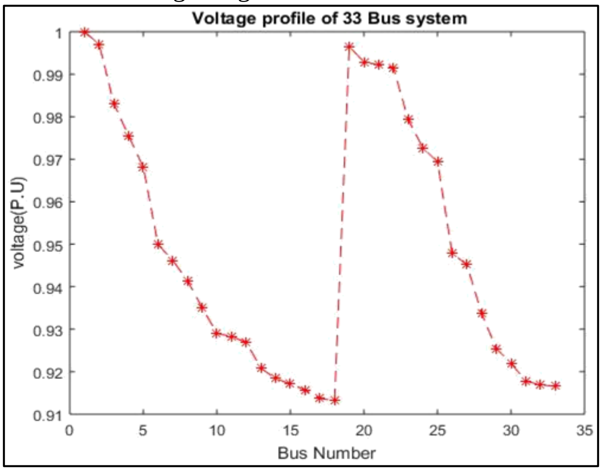

Fig. 3: Voltage Magnitude Profile

The bus having minimum voltage is the most sensitive bus which is selected to install DG in the system. From Fig. 3 it is observed that bus 18 has minimum voltage.

By optimally allocating the DG in the distribution system, the active and reactive power losses in the system are reduced and the system voltage profile is improved. The voltage profiles of the system before placement of DG and after placement of DG using PSO are shown in Fig. 4.

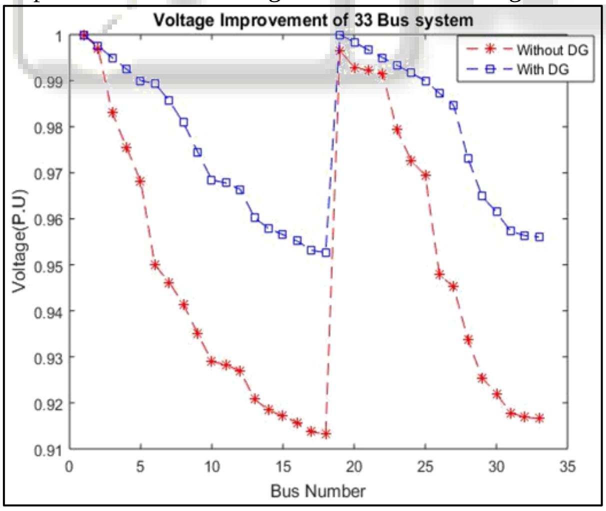

Fig. 4: Voltage Profile Comparison

Using the PSO algorithm, the optimal size of DG unit is determined. Table II represents the real and reactive power loss reduction after placing a DG using PSO.

	Base Case (without DG)	PSO	Loss reduction (%)
DG location	-	18	-
DG size (MW)	-	0.529	-
Real power loss (kW)	208.28	150.4	27.79
Reactive power loss (kVar)	139.3	115.17	17.32

Table 2: Power Loss Reduction

V. CONCLUSION

In view of ever-increasing load demand in the power sector, DG is playing a very vital role to improve the system performance by reducing the real power losses and improving the voltage profile. Optimal capacity and location of DG are very significant in the application of DG for loss minimization and voltage profile improvement in electric power system. Improper placement of DG in the system operation will lead to the negative effect on system operation. This paper presents new population based heuristic methods i.e. PSO algorithms is used to place the optimal sizing of DG at suitable location. The optimal location for placing the DG is identified with comparatively less voltage profile. IEEE-33 bus system is examined and the results are obtained. The power loss results are tabulated and the voltage profile improvement is shown graphically. Thus, it is concluded that the losses are reduced to a large extent and voltage profile is improved by placing the suitable size of DG which is obtained by using PSO.

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