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Renewable Resource Based DG Unit Allocation in Distribution System via PSO

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Abstract-- Recently, integration of Distributed generation (DG) in distribution system has increased to high penetration levels. The impact of DG on various aspects of distribution system operation, such as reliability and energy loss depend highly on DG location in distribution feeder .Optimal DG placement plays an important role .This paper proposes the application of Particle Swarm Optimization for the placement of DG in the radial distribution systems to reduce the real power losses and to improve the voltage profile .The proposed technique is tested on standard IEEE-33 bus test system.

Keywords: Distributed generation (DG), placement, Particle swarm optimization, Radial distribution.

I. INTRODUCTION

The anguish about rising environmental population and also the concern about the fossil fuels problems and limitations led to the installation of Distributed Generation (DG) which increases annually. In order to improve voltage profile, stability, reduction of power losses and etc, it is necessary that this increasing of installation of DGs in Distribution system should be systematically .Most countries generate electricity in large centralized facilities, such as fossil fuel (coal, gas powered), nuclear, large solar power plants or hydropower plants. These plants have excellent economies of scale, but usually transmit electricity long distances and can negatively affect the environment. Distributed generation allows collection of energy from many sources and may give lower environmental impacts and improved security of supply. Distributed generation (DG) is not a new concept but it is an emerging approach for providing electric power in the heart of the power system. It mainly depends upon the installation and operation of a portfolio of small size, compact, and clean electric power generating units at or near an electrical load (customer). Surveying DG concepts may include DG definitions, technologies, applications, sizes, locations, DG practical and operational limitations, and their impact on system operation and the existing power grid. This work focuses on surveying different DG types, technologies, definitions, their operational constraints, placement and sizing with new methodology particle swarm optimization. Particle swarm optimization (PSO) is used in this paper in order to find solution to optimization problems, optimal size and site of DG in 33- bus system. The aim of this paper reduction in real power losses, reactive power and improving the voltage profile. The simulation test systems were simulated in MATLAB.

II. TOTAL REAL POWER LOSS IN A SYSTEM

The total power loses in a distribution system having N number of branches

$$P_{LT} = \sum_{I=1}^{N} I_i^2 Ri \qquad (1)$$

Ii is the magnitude of the branch current and Ri is the resistance of the I th branch respectively. The branch current can be obtained from load flow analysis. The branch current has two components (Ir) reactive component and active component (Ia).The loss associated with each components of branch current can be written as:

$$P_{La} = \sum_{i=1}^{N} I_{ai}^2 Ri \qquad (2)$$

$$P_{Lr} = \sum_{i=1}^{N} I_{ri}^2 Ri \qquad (3)$$

2.1 Optimal DG Size And Location

The optimal size of DG is calculated at each bus using the exact loss formula and the optimal location of DG is

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found by using the loss sensitivity factor. The loss sensitivity factor is used for the placement of DG is explained as, the real power loss in the system is given by

$$P_L = \sum_{i=1}^{N}\sum_{i=1}^{N}[\alpha_{ij}(P_iP_j + Q_iQ_j) + \beta_{ij}(Q_iP_j + P_iQ_j) \quad (4)$$

Where

$$\alpha_{ij} = \frac{r_{ij}}{v_iv_j}\mathrm{Cos}(\delta_i - \delta_j) \quad (5)$$

$$\beta_{ij} = \frac{r_{ij}}{v_iv_j}\mathrm{Sin}(\delta_i - \delta_j) \quad (6)$$

and

$z_{ij} = r_{ij} + jx_{ij}$

ij are the element of Z bus matrix

$P_i = P_{Gi} - P_{Di}$ and $Q_i = Q_{Gi} - Q_{Di}$

P_{Gi} & Q_{Gi} are power injection of generators to the bus.

P_{Di}, Q_{Di} are the loads.

P_i, Q_i is active and reactive power of the buses.

The sensitivity factor of real power loss with respect to real power injection from the DG is given by

$$\alpha_i = \frac{\partial P_L}{\partial P_i} = 2\alpha_{ii}P_i + 2\sum_{\substack{j=1\\j\neq i}}^{N}(\alpha_{ij}P_j - \beta_{ij}Q_j) \quad (7)$$

Sensitivity factor are evaluated at each bus by using the values obtained from the base case load flow. The bus having lowest loss sensitivity factor will be best location for the placement of DG.

$$\frac{\partial P_L}{\partial P_i} = 2\alpha_{ii}P_i + 2\sum_{\substack{j=1\\j\neq i}}^{N}(\alpha_{ij}P_j - \beta_{ij}Q_j) = 0 \quad (8)$$

The total power loss against injected power is parabolic function and at a minimum losses ,the rate of changes of loss with respect to injected power is zero.

Then the above equation becomes

$$P_i = \frac{1}{\alpha_{ii}}\left[\sum_{\substack{j=1\\j\neq i}}^{N}(\alpha_{ij}P_j - \beta_{ij}Q_j)\right] \quad (9)$$

Where P_i is the real power injection at node i, which is the difference between real power generation and the real power demand on that node

$$P_i = (P_{DGi} - P_{Di}) \quad (10)$$

Where P_{DGi} is the real power injection from DG placed at node i, and P_{Di} is the load demand at node i. By combining the above we get.

$$P_{DGi} = P_{Di} - \frac{1}{\alpha_{ii}}\left[\sum_{\substack{j=1\\j\neq i}}^{N}(\alpha_{ij}P_j - \beta_{ij}Q_j)\right] \quad (11)$$

The above equation gives the optimum size of DG for each bus i, for the real power loss to be minimum and any size of DG other than Pdgi placed at bus i,means it will create a higher loss.

III. OPTIMAL LOCATION OF DG

The allocating optimal location is find for the placement of accurate size of DG at the respective bus as shown in fig (1) and which will produce the lowest loss due to the placement of DG at the respective bus is shown fig(2).and this figure is for single DG placement in a bus system .

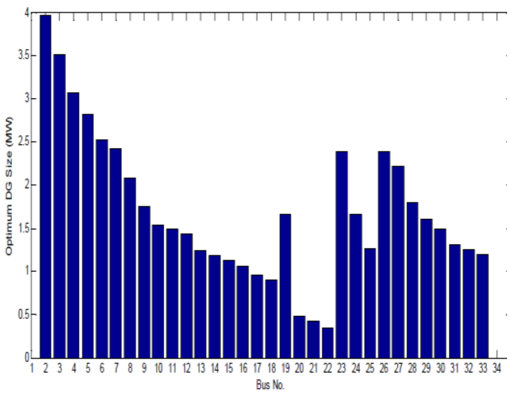

Figure 1. Optimum size of DG at various locations for 33 bus distribution system

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IV. PROBLEM FORMULATION

Analytical expression, the optimum size of DG is calculated at each bus for the test system and bus having least total power loss will be the optimal location for the placement of DG; the best location is bus 6 with a total power loss of 111.2 kW, but this approach violates the voltage limits as shown in fig.(2).

The optimal placement of DG by loss sensitivity approach is not able to identify the best location. If voltage limits are taken into consideration then size of DG will increase but if the same is done by PSO technique by taking the voltage limit constraints into consideration the size of DG will decrease drastically i.e. 240kW, with approximately same power loss which is shown in given table. The optimal placement of DG by PSO technique taking the voltage limits of the system into consideration to minimizing the real power loss improves the results drastically.

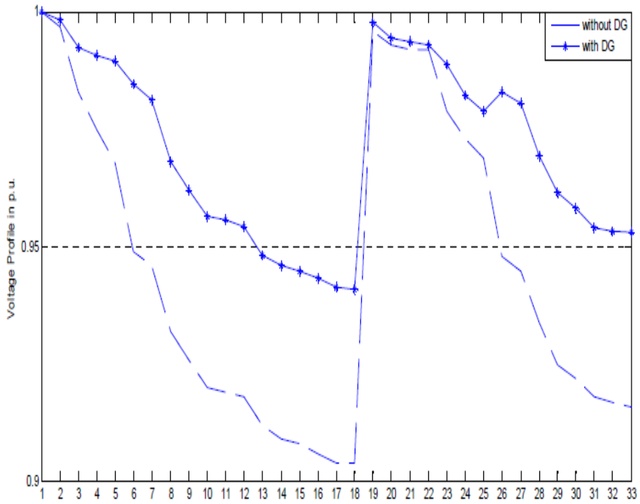

Figure 2. variation of voltage profile by analytical method.

Table(1) Power loss with and without DG for 33 bus system without limits

Method	Optimum location	Optimum DG size (MW)	Power loss (KW)	
			Without DG	With DG
Analytical approach	Bus 6	2.49	210.97	111.2
Loss sensitivity factor	Bus 10	1.4	210.97	123.72

4.1 Voltage limits

The voltage limits depend on the voltage regulation limits should be satisfied this voltage constrained equation:

$$V_i^{min} \leq V_i \leq V_i^{max} \qquad (12)$$

Table(2) Power loss with and without DG for 33 bus system with limits

METHOD	OPTIMUM LOCATION	OPTIMUM DG SIZE(MW)	POWER LOSS (kW)	
			Without DG	With DG
Repeated load flow	BUS 6	3.15	210.97	115.2
PSO	BUS 6	2.59	210.97	111.1

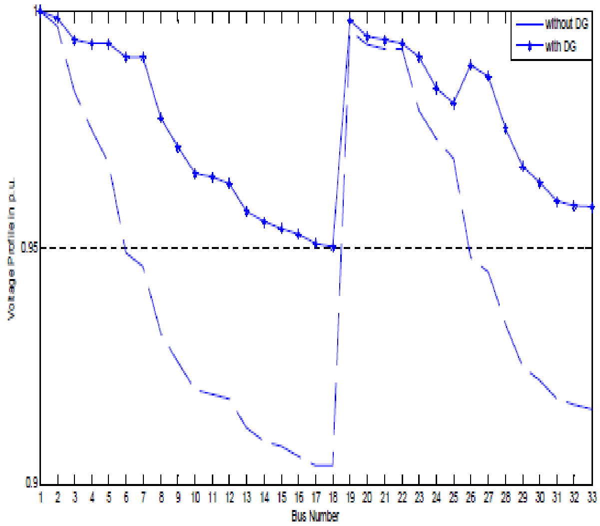

Figure 3. variation of voltage profile by analytical method.

4.2 Multiple Dg Placement:

This paper introduces the Multiple objective function (MOF) for placing the DG in distribution network to reduces the losses in the systems.

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Max f (P_{loss}, Q_{loss}, I_{SC}, V_{level}).

Where:

$$f(P_{loss}, Q_{loss}, Isc, V_{level}) = w_1F_p + w_2F_q + w_3F_i + w_4F_v$$

4.3 Power-conservation limits:

The algebraic sum of all the incoming and outgoing power including line losses over the whole distribution network and power generated from DG unit should be equal to zero.

$$P_{Gen} + P_{DG} - \sum_{i=1}^{n} P_D - P_{total}^{Loss} = 0$$

4.4 Distribution line capacity limits:

Power flow through any line must not exceed the thermal capacity of the line

$$S_{ij} < S_{ij}^{\max}$$

V.PARTICLE SWARM OPTIMIZATION

Particle swarm optimization (PSO) is a population-based optimization method first proposed by Kennedy and Eberhart in 1995, inspired by social behavior of bird flocking or fish schooling (Kennedy et al, 1995). The PSO as an optimization tool provides a population-based search procedure in which individuals called particles change their position (state) with time. In a PSO system, particles fly around in a multidimensional search space. During flight, each particle adjusts its position according to its own experience (This value is called Pbest), and according to the experience of a neighboring particle (This value is called Gbest), made use of the best position encountered by itself and its neighbor fig(4).

$$v_{id}^{k+1} = \omega v_{id}^{k} + c_1 rand \times (pbest_{id} - s_{id}^{k}) + c_2 rand \times (gbest_{id} - s_{id}^{k})$$

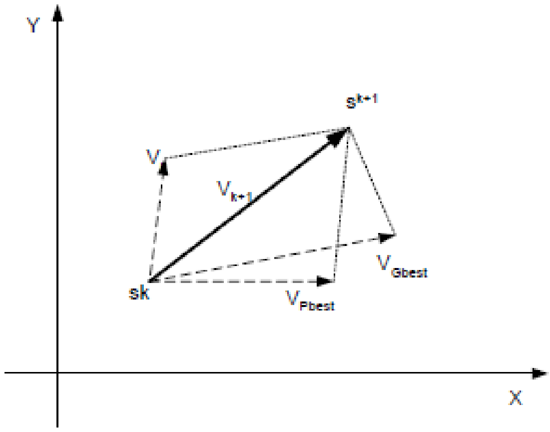

Fig (4) searching point of pso

The current position can be modified based on the new velocity of the search particle

$$s_{id}^{k+1} = s_{id}^{k} + v_{id}^{k+1}, i = 1,2,\ldots,n .$$

Where, d=1,2,3….m

s^k is current searching point,

s^{k+1} is modified searching point,

v^k is current velocity,

v^{k+1} is modified velocity of agent *i*,

5.1 Objective Of Pso :

The main objective is to minimize the total power loss as given in eq. (1) while meeting the following constraints.

- The network power flow equation must be satisfied.
- The voltage at every bus in the network should be within the acceptable range that is

$V_{min} \le V_i \le V_{max}$

To obtain the fitness function .

5.2 PSO Procedure

The PSO-based approach for solving the OPDG problem to minimize the loss takes the following steps:

Step 1: Input line and bus data, and bus voltage limits.

Step 2: Calculate the loss using distribution load flow based on backward-forward sweep.

Step 3: Randomly generates an initial population (array) of particles with random positions and velocities on dimensions in the solution space. Set the iteration counter k = 0.

Step 4: For each particle if the bus voltage is within the limits, calculate the total loss in equation. Otherwise, that particle is infeasible.

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Step 5: For each particle, compare its objective value with the individual best. If the objective value is lower than Pbest, set this value as the current Pbest, and record the corresponding particle position.

Step 6: Choose the particle associated with the minimum individual best Pbest of all particles, and set the value of this Pbest as the current overall best Gbest.

Step 7: Update the velocity and position of particle using the equation respectively.

Step 8: If the iteration number reaches the maximum limit, go to Step 9. Otherwise, set iteration index k = k + 1, and go back to Step 4.

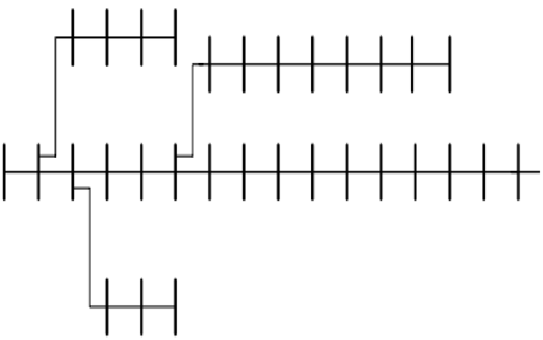
Step 9: Print out the optimal solution to the target problem. The best position includes the optimal locations and size of DG or multi-DGs, and the corresponding fitness value representing the minimum total real power loss.

VI. RESULTS AND DISCUSSION

The algorithm of this method was programmed in MATLAB. The ABC algorithm for distribution system was tested the 33 bus systems. The 33 bus system has 32 sections with the total load 3.72 MW and 2.3MVar shown in Figure.

The original total real power loss and reactive power loss in the system are 221.4346 kW and 150.1784 kVar, respectively. For the first iteration the maximum saving is occurring at bus 6. The candidate location for DG is bus 6 with a loss saving of 92.1751 kW. The optimum size of DG at bus 6 is 2.4886 MW. By assuming 2.4886 MW DG is connected at bus 6 of base system and is considered as base case. Now the candidate location is bus 15with 0.4406 MW size and the loss saving is 11.4385 KW.

Fig 5-IEEE 33 Bus System



Matlab output

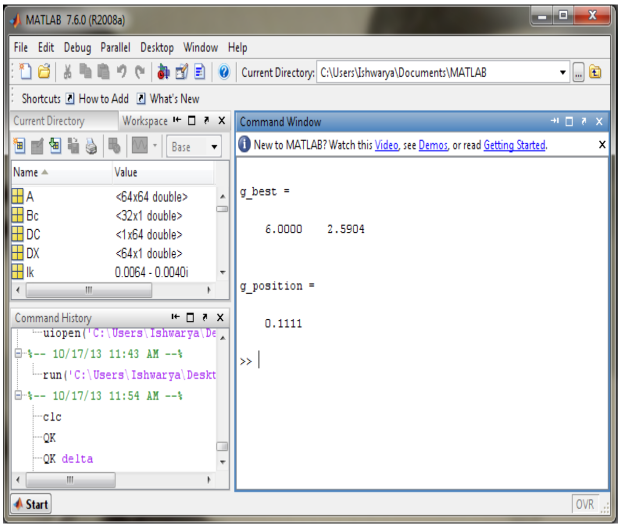


Table 3: Single DG placement with loss reduction

iteration No.	Bus No.	DG Size (MW)	Saving (KW)
1	6	2.4886	92.1751
2	15	0.4406	11.4385
3	25	0.6473	7.6936
4	32	0.4345	8.1415

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Table 4:Multiple DG placement with loss reduction

Case	bus locations	DG SIZE (MW)	Total Size(MW)	losses before DG installation (Kw)	loss after DG installation (Kw)	saving(Kw)	saving/DG size
I	6	2.5	2.5775	203.9088	105.02	98.88	39.9
II	6	1.9707			89.9619	113.947	44.75
	15	0.5757	2.5464				
III	6	1.7569			79.2526	124.656	40.015
	15	0.5757					
	25	0.7826	3.1152				
IV	6	1.0765			66.5892	137.32	44.86
	15	0.5757					
	25	0.7824					
	32	0.6538	3.0884				

VII. CONCLUSIONS

In this project, a two-stage methodology of finding the optimal locations and sizes of DGs for maximum loss reduction of radial distribution systems is presented. Single DG placement method is proposed to find the optimal DG locations and pso algorithm is proposed to find the optimal DG sizes. The validity of the proposed method is proved from the comparison of the results of the proposed method with other existing methods. The results proved that the pso algorithm is simple in nature than GA so it takes less computation time. By installing DGs at all the potential locations, the total power loss of the system has been reduced drastically and the voltage profile of the system is also improved. Inclusion of the real time constrains such as time varying loads and different types of DG units and discrete DG unit sizes into the proposed algorithm is the future scope of this work.

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