OPTIMAL LOCATION AND SIZING OF DISTRIBUTED GENERATOR IN RADIAL DISTRIBUTION SYSTEM USING OPTIMIZATION TECHNIQUE FOR MINIMIZATION OF LOSSES

A. Vishwanadh[1], G. Sasi Kumar[2], Dr. D. Ravi Kumar[3]
[1](Department of EEE, VNRVJIET, Hyderabad
Email:akunuri.vishwanadh@gmail.com)
[2, 3] (Department of EEE, VNRVJIET, Hyderabad
Email: sasikumar_g@vnrvjiet.in[2], ravikumar_d@vnrvjiet.in[3])

ABSTRACT

Recently, there has been a great interest in the integration of distributed generation units at the distribution level of the Power system. The Foreseeable large use of DG in the future requires the distribution system engineers to properly take into account its impact in the system planning. When considering DG impact the attention should be paid in the location and sizing of DG units. Proper location of DGs in power systems is important for obtaining their maximum potential benefits like improved voltage profile, loss reduction, increase in reliability, improved voltage stability index. In this paper Particle Swarm Optimization algorithm is proposed to solve the problems faced in sensitivity analysis approach to find the optimal location and size of DG for minimization of losses and enhance the voltage profile and voltage stability index in distribution systems is tested on IEEE 33-bus radial distribution system to demonstrate the test results in the presence of DG.

Keywords *– Distribution Generation, Particle Swarm Optimization, Radial Distribution, sensitivity, Voltage Stability Index.*

1. INTRODUCTION

Electricity is one of the main and basic inputs necessary for the economic development of a country. The rapid economic development and industrialization of our country has created a critical need for the additional power even though, there has been a spectacular growth in power generation. However, due to several reasons the suppliers are not able to meet the power demand. The Electrical energy is continuously lost due to resistance in power system and distribution system loss accounts more compared to transmission system due to the higher R/X ratio.

The objective of the power system operation is to meet the demand at all the locations within the power network as economically and reliably as possible. To minimize the losses in the distribution system the Distributed Generations (DGs) are introduced in to the network. DGs generally refer to small-scale (typically 1 kW – 50 MW) electric power generators that produce electricity at a site close to customers or that are tied to an electric distribution system.

Load flow studies are performed on power systems to understand the behavior of the installed system. This gives the complete details of the system like loads connected, power flow in the lines, voltage levels, losses in the lines and generating unit and also helps in estimating for the future expansion of the system. In Distribution System because of high R/X ratio, it does not allow the transmission load flow study methods such as Newton Raphson and FDLF to use efficiently. So radial distribution load flow studies such as Bee Colony Algorithm, Ant Colony algorithm, Distribution load flow, Forward and Backward Sweep algorithm etc are used. In this paper load flow study is carried out by using Forward Sweep and Backward Sweep method[1][2]. The sensitivity analysis of a system gives the advantage of avoiding repeated power flow. Sensitivity factors for the distribution system analysis were derived based on the linear power flow formulation. these can be advantageous in placing the DGs , capacitors ,network reconfiguration etc. The loss sensitivity factor is used in this paper to identify the DG location [3][4].The particle swarm optimization method is used to identify the location and size of the DG for this solution[1][5][6]. The voltage stability analysis of a system plays a major role in the operation of the system. Voltage stability index(VSI) based on steady state analysis is more feasible. This provides to determine the weakest node which is sensitive to collapse.[9][10].

In this paper problem formulation is discussed in section 2, sensitivity analysis approach and PSO approach are described in section 3 and 4. Voltage stability index is discussed in section 5. Result analysis in section 6 and conclusions are presented in section 7.

2. PROBLEM FORMULATION

The objective function of this DG placement is mainly to reduce the losses. In the proposed algorithm of DG sizing the fitness function considered for minimization of total active power losses (P_L), given by the equation

$$F = \min(P_L) = \sum_{i=1}^{n} I_i^2 R_i \tag{1}$$

where I is the line current in branch I
R is the resistance of the branch i
N is the total number of branches

3.1 EQUALITY CONSTRAINTS

The equality constraint is the power balance equation in which the total power generated in the system should be equal to the sum of the total power demand and the total transmission losses of the system.

$$\sum_{i=1}^{N} P_{Gi} = P_{Di} + P_L \tag{2}$$

3.2 INEQUALITY CONSTRAINTS

Voltage limits for each bus, there should be an upper and lower voltage bounds

$$0.95 \le V_i \le 1.05 \tag{3}$$

3. SENSITIVITY ANALYSIS FOR DG LOCATION AND SIZE

Sensitivity factor method is based on the principle of linearization of original nonlinear equation around the initial operating point, this helps to reduce the number of solution space.

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 (1).This formula is popularly referred as "Exact Loss" formula [4].

$$P_L = \sum_{i=1}^{N}\sum_{j=1}^{N}\left[\alpha_{ij}\left(P_iP_j + Q_iQ_j\right) + \beta_{ij}\left(Q_iP_j - P_iQ_j\right)\right] \tag{4}$$

where

$$\alpha_{ij} = \frac{r_{ij}}{V_iV_j}\cos\left(\delta_i - \delta_j\right) \tag{5}$$

$$\beta_{ij} = \frac{r_{ij}}{V_iV_j}\sin\left(\delta_i - \delta_j\right) \tag{6}$$

$Z_{ij} = r_{ij} + jx_{ij}$ are the ijth element of [Zbus] 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 are active and reactive power of the bus.

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

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

4.1 OPTIMAL LOCATION OF DG

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

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

Computing the equation(8) yields

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

P_i is the real power injection at node I, which is the difference between real power generation and real power demand

$$P_i = P_{DGi} - P_{Di} \tag{10}$$

P_{DGi} is the real power injection from DG placed at node i.

P_{Di} is the load demand at node i.

4.2 OPTIMAL SIZE OF DG

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

The equation gives the optimum size of DG for each bus i , for the loss to be minimum. Any size of DG other than P_{DGi} placed at bus i, will lead to higher loss

To ensure a high-quality product, diagrams and lettering MUST be either computer-drafted or drawn using India ink. Figure captions appear below the figure, are flush left, and are in lower case letters. When referring to a figure in the body of the text, the abbreviation "Fig." is used. Figures should be numbered in the order they appear in the text.
Table captions appear centered above the table in upper and lower case letters. When referring to a table in the text, no abbreviation is used and "Table" is capitalized.

4. OVERVIEW OF PSO

PSO is a heuristic search algorithm which was introduced by Kennedy and Eberhart. It is a random search algorithm, which imitate the behavior of particles in the swarm like fish schooling, birds flocking and the swarm theory. It is a population based search procedure in which individuals called particles approaches to the optimum or a quasi-optimum with some velocity in a multi-dimensional search space based on its own experience and its neighbors experience.

The position and velocity of i^{th} particle in a n-dimensional search space are represented as the vectors $X_i = (x_{i1},x_{i2},\ldots x_{in})$, and $V_i=(v_{i1},v_{i2},\ldots v_{in})$, respectively. Let $Pbest_i = (x_{i1}^{best},x_{i2}^{best},\ldots x_{in}^{best})$, and $Gbest=(x_{i1}^{Gbest},\ldots x_{in}^{Gbest})$ respectively, be the local best position of individual 'i' and global best position so far. The velocity of each particle can be updated using the following equation [13]

$$V_i^{k+1} = \omega V_i^k + c1 \times rand1 \times (Pbest_i^k - X_i^k) + c2 \times rand2 \times (Gbest^k - X_i^k) \quad (12)$$

Where,

V_i^k =Velocity of particle at iteration k

ω= inertia weight factor

c1,c2= acceleration coefficients

rand1, rand2= random numbers between 0 and 1

X_i^k = Position of particle at iteration k

$Pbest_i^k$ = best position of particle until iteration k

$Gbest^k$ = best position of the group until iteration k

Each particle in a population moves from the current position to the next position by the modified velocity in (12) using the following equation:

$$X_i^{k+1} = X_i^k + V_i^{k+1} \quad (13)$$

Where,

X_i^{k+1}= Position of particle at iteration (k+1).

4.1 PSO FLOWCHART

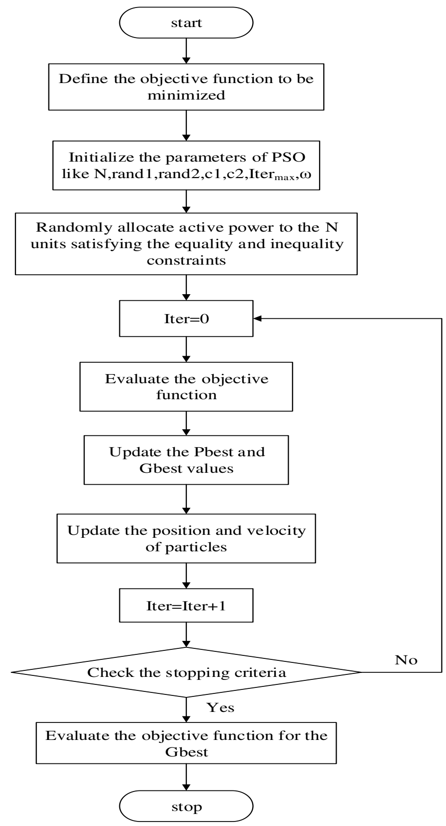

Fig.1 Flow chart of PSO

4.2 PSO ALGORITHM

This method is applied to obtain the optimal or near optimal location of the each generating unit using PSO algorithm. The sequence of steps of the applied method is given below:

Step 1: Initialize the objective Function and the PSO parameters like Population size N, C1, C2, ω_{max}, ω_{min}, rand1, rand2, iter, $iter_{max}$, MW limits of the generating stations and the total power demand.

Step 2: Initialize the position of each individual (or particle) which satisfy both equal and inequality constraint.

Step 3: Initialize the velocity of each individual by using the following strategy

$$P_j^{\min} - P_{ij}^0 \le V_{ij}^0 \le P_j^{\max} - P_{ij}^0$$

Where,

V_{ij}^{o}= initial velocity of j^{th} element of particle i

P_{ij}^{0}= initial position of j^{th} element of particle i

Step 4: The initial individual position is the initial local best (Pbest) of each particle. Evaluate the objective function for each individual with initial positions and the position of the particle which gives best solution among all the particles is the initial global best (Gbest).

Step 5: The velocity of each individual can be updated using the "(12)" for the calculation of the velocity of each individual the weight factor is defined as follows:

$$\omega = \omega_{\max} - \frac{\omega_{\max} - \omega_{\min}}{iter_{\max}} \times iter$$

Where,

ω_{min}, ω_{max} are initial and final weights

$Iter_{max}$= maximum number of iterations

Iter=current iteration number

Step 6: The position of each particle is updated using the (13). Each element in the particle is checked for its inequality constraint in (3), if it violates the limits it is adjusted to its max or min limit value based on its violation.

Step 7: Check whether the summation of all the elements in a individual is equal to total demand using (2). If it is not satisfied modify an element (let l=1) in a particle to a value which is obtained by subtracting the sum of remaining elements in a particle from total demand.

Step 8: If the modified element in a particle doesn't satisfy inequality constraint then adjust the value to its boundary value then set l=l+1 and go to step 7. Otherwise go to step 9.

Step 9: Evaluate the objective function at each iteration and update the Pbest and Gbest values.

Continue the above mentioned process till stopping criteria ($iter=iter_{max}$) is met. This final value of Gbest gives the optimum solution.

TABLE 1	
PSO Parameters for the system	
Number of particles	50
Inertia weight W_1	0.4
Inertia weight W_2	0.9
No of iterations	100
Voltage level V_{min}	0.95
Voltage level V_{max}	1.05
Constriction factors c1,c2	2.05

5. VOLTAGE STABILITY INDEX

Voltage stability index identifies the node which is more sensitive to voltage collapse in the system.

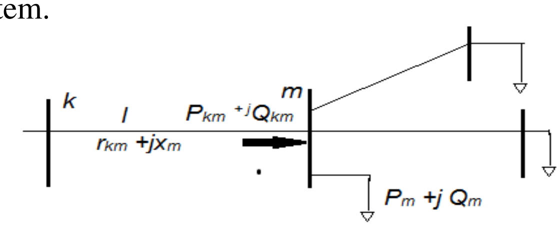

Fig. 2 simple distribution line

From fig.2

Where V_k= voltage magnitude at node –k , V_m= voltage magnitude at node –m , r_{km} + j X_{km} resistance and reactance of node of line-l l distribution line connected between buses k and m

P_{km} sum of real power loads of all nodes beyond node-m plus real power load of node-m itself plus the sum of real power losses of all branches beyond node-m

Q_{km} sum of reactive power loads of all nodes beyond node-m plus reactive power load of node-m itself plus the sum of reactive power losses of all branches beyond node-m

P_m + Q_m real and reactive power load at node-m

$$VSI(m) = V_k^4 - 4(P_{km}x_{km} - Q_{km}r_{km})^2 - 4(P_{km}r_{km} + Q_{km}x_{km})V_k^2 \quad (14)$$

Where VSI(m)= voltage stability index at node m

For stable operation of the radial network VSI(m) ≥0 the node at which the value of the stability index is minimum is more sensitive to voltage collapse

6. RESULT AND DISCUSSION

The proposed method is tested on IEEE 33-BUS radial distribution system. A separate computer program has been written in MATLAB version 9 for both sensitivity analysis method and PSO method to calculate the optimum location and size of Distributed Generator and Voltage stability index (VSI). The IEEE 33-bus standard data is considered [7][8].The Base MVA and Base KV of the system is 100 an 12.66. Losses in the test case IEEE 33 bus system obtained with Forward and Backward Sweep load flow algorithm are **202.3861** kW real **134.9504** kVAr.

By using the sensitivity analysis method for the optimal location and sizing of the DG in the system,test results shows that there is a reduction of active power losses in the system after placing the DG. The results are shown in table 2 and the voltage profile is shown in fig 3

Table 2	
Results after placing DG Using LSF	
Real power losses kW	147.64
Reactive power losses KVAr	106.26
Optimal size of DG(MW)	1.3902
Optimal Location	5
% reduction in Active power loss	27.048

By using the PSO method for the optimal location and sizing of the DG in the system, test results shows that there is a reduction of active power losses in the system after placing the DG. The results are shown in table 3 and the voltage profile is shown in Fig 3

Table 3	
Results after placing DG Using PSO	
Real power losses kW	104.018
Reactive power losses KVAr	74.71
Optimal size of DG(MW)	2.49
Optimal Location	6
% Reduction of active power loss	48.60

The voltage stability index for the base case and condition after the placement of the DG in the test system are tabulated.Results show that the VSI of the system is improved considerably.The results are shown in table 4.

Table 4	
Results of VSI before and after DG	
Case	Voltage Stability Index
Base case	0.693224
Placing DG with LSF method	0.733190
Placing DG with PSO	0.811843

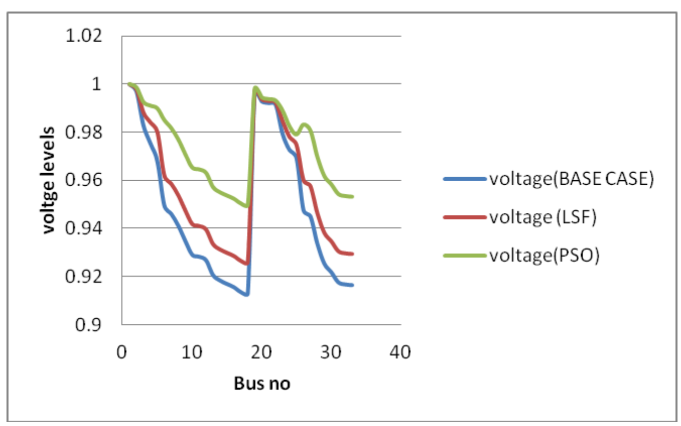

Fig.3 comparison of voltages before and after DG placement

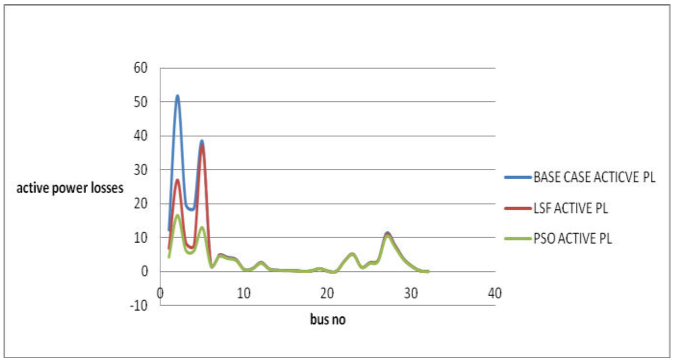

Fig4: comparison of Active power losses before and after DG placement

7. CONCLUSION

The inclusion of DG into Distribution system yields many benefits such as line loss reduction, increasing Reliability and improved voltage profile .This paper proposes two algorithms to find the optimal size and optimal location of the DG unit and tested on IEEE 33 RDS for minimization of losses i.e., Sensitivity analysis using LSF and search algorithm Particle Swarm Optimization. The results show that in the proposed methods the PSO method shows superior performance than sensitivity analysis method. The system voltage stability has been significantly improved. This proposed method is implemented for higher order system.

REFERENCES

[1] J. A. Michline Rupa, S. Ganesh, "Power Flow Analysis for Radial Distribution System Using Backward/Forward Sweep Method" International Journal of Electrical, Computer, Energetic, Electronic and Communication Engineering Vol:8, No:10, 2014

[2] A. AppaRao, M. Win Babu, " Forward Sweeping Method for Solving Radial Distribution Networks", IJAREEIE Vol. 2, Issue 9, September 2013

[3] Satish Kansal, B.B.R. Sai, Barjeev Tyagi, Vishal Kumar "Optimal placement of distributed generation in distribution networks", International Journal of Engineering Science and Technology,Vol. 3, No. 3, 2011, pp. 47-55

[4] Gungor , R.B., et al. : A Technique for optimizing Real and Reactive power schedules , IEEE Trans vol. PAS-90,No.4, pp.1781-1790 , July/Aug.1971.

[5] M. M. Aman, G. B. Jasmon, H. Mokhlis, and A. H. A. Bakar, "Optimal placement and sizing of a DG based on a new power stability index and line losses," International Journal of Electrical Power & Energy Systems, vol. 43, pp. 1296-1304, 2012.

[6] A. Apparao, K. Bhashna , " Optimal Allocation of DG Considering Loss Minimization and Voltage Profile Using PSO," International Journal of Science and Research (IJSR), Volume 4 Issue 9, September 2015

[7] D. Ravi kumar and V.sankar, "Loss reduction and reliability optimization in electrical distribution systems using network reconfiguration", The Journal of CPRI, Vol. 11, No.2, June 2015.

[8] Kashem M.A., Ganapathy V., Jasmon G.B., Buhari M.I., 2000. A novel method for loss minimization in distribution networks, Int.Conference on Electric Utility Deregulation and Restructuring and Power Technology, London, April.

[9] G.V.K Murthy., S. Sivanagaraju., S. Satyanarayana., B. Hanumantha Rao., "Voltage Stability Analysis of Radial Distribution Networks with Distributed Generation", International Journal on Electrical Engineering and Informatics - Volume 6, Number 1, March 2014

[10] M. Chakravorty., D. Das., "Voltage stability analysis of radial distribution networks" Electrical Power and Energy Systems 23 (2001) 129-135