Analysis of Radial Distribution System By Optimal Placement of DG Using DPSO

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Abstract

This paper aims to discuss the placement of Distributed Generation (DG) using Discrete Particle Swarm Optimizaiton (DPSO) algorithm in order to reduce the real power loss and improve the voltage profile. The objective function is based on real power loss reduction with relevant constraints. The proposed method deals with selection of nodes for the placement of DG and size of the DG by using DPSO. The proposed algorithm is tested with two systems consisting of 33 node and 69 node radial distribution systems.

Keywords: Distributed Generation, Radial Distribution System, Load flow, Discrete Particle Swarm Optimization

1. Introduction:

A distribution system is one from which the power is distributed to various users through feeders, distributors and service mains. Distribution system provides a final link between high voltage transmission systems and consumer services. The operation and planning studies of a distribution system require a steady state condition of the system for various load demands. The power losses are significantly high in distribution because of lower voltages and high currents, when compared with high voltage transmission systems. Reduction of total losses in the distribution systems is very essential to improve the overall efficiency of the distribution system. Therefore loss minimization in radial distribution systems has become the subject of intensive research. The performance of the distribution network can be extremely improved by using suitable methods like optimal placement of distributed generators.

Distributed or dispersed generation may be defined as a generating resource, other than central generating station, that is placed close to load being served, usually at customer site. It may be connected to the supply side or demand side of meter. It can be a renewable energy source based micro, hydro, wind turbines, photovoltaic, or fossil fuel based. In terms of size, DG may range from a few kilowatts to over few megawatts. They are used to reduce power losses and to maintain a voltage profile within the acceptable limits. Proper placement of DG results in to a number of benefits like improvement of power loss reduction, improvement of voltage profile, improvement of voltage stability, system-released capacity, increases voltage level at the load, and improvement of voltage regulation. The extent of these benefits depends on the location, size, and number of the DGs to be installed.

The placement and sizing of generation units are important issues on an actual electrical system planning, because installing generators at certain points of the feeder can bring in one or just a few capacity gains. In some cases it is not possible to install generator only at those nodes indicated by an optimal algorithm, since independent producers and even consumers can request their access to the network in other places. In addition there may not be generation potential at some point. Even so, utilities are interested in methods which allow them to evaluate the impact of generation units in their system for reorienting them on how to deal with new producers about the possible installation points.

In the past decades, several attempts were made to improve the voltage profile and hence to reduce the power losses by placing distributed reactive power sources such as capacitor bank of optimal sizes at optimal location [1-4]. The radial distribution systems are less reliable because of its passive nature. Recently, solutions have been suggested for complementing the passiveness of RDS by embedding electrical sources of small capacity based on renewable energy technology to improve system reliability and voltage regulation [5],[6]. Such embedded generations in the distribution system are also called as dispersed generations or distributed generations (DG).

The benefits and consequences of DG had been dealt in several papers [7-10]. Recently, power loss reduction has been addressed using DG, reactive power sources and network reconfiguration [11]. However, the details of reactive power management with respect to the type of DG technology employed were not discussed in [11]. This paper explores the possibility of effective power flow control in radial distribution systems using distributed generations for improving voltage profile, voltage stability index and power loss reduction in the RDS.

Particle swarm optimization (PSO) is an evolutionary computation technique developed by Kennedy and Eberhartin 1995 [12, 13]. The PSO technique has ever since turned out to be a competitor in the field of numerical optimization. Perhaps more obvious are its ties to artificial life (A-life) in general, and to bird flocking, fish schooling, and swarming theory in particular. The first version of PSO was intended to handle only nonlinear continuous optimization problems. PSO has been expanded to handle both discrete and continues variables as well.

There are various ways for obtaining the optimal location and optimal sizing of DG. In [14], sensitivity analysis is used for finding the optimal location of DG. In [15] the optimal location is found by finding Vindex. In [16] Loss sensitivity factor is used for finding the optimal location of DG. This paper finds the optimal location of DG using DPSO and also finds the optimal sizing using DPSO, compares the results with VSI and concludes that using DPSO is better option for finding the optimal location and optimal sizing of DG.

2. Load Flow solution of RDS:

In order to evaluate the performance of a power distribution system and to examine the effectiveness of proposed alterations to a system in the planning stage, it is essential that a load flow analysis of the system is to be carried out. One of the most fundamental and widely used analysis tool to study radial distribution system is load flow analysis.

A simple approach of backward and forward sweep [17] is carried out for load flow analysis of the given system.

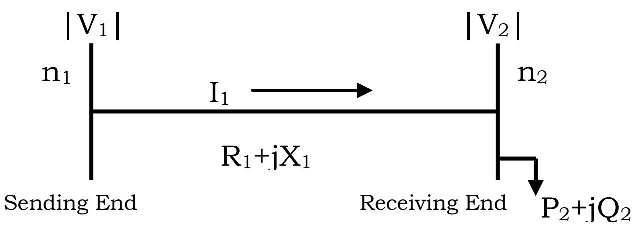

Fig:1 Single Line Diagram of a Branch

Find Line Current at each node given by eqn(1)

$$I_L(n) = \left(\frac{S(n)}{V(n)}\right)^* \quad \text{---------- (1)}$$

$$\text{where } n = 1, 2, 3, \ldots\ldots Nn$$

Find the Branch Current at each branch given by eqn.(2) in minor, sub-lateral, lateral and main lines from last node to the root node.

$$I_b(n) = I_b(n+1) + I_L(n+1)$$
$$\text{where } n = 1, 2, 3, \ldots\ldots Nb \quad \text{---------- (2)}$$

Find the new voltages at each node given by eqn.(3) in main, lateral, sub-lateral and minor lines from root node to the end node.

$$V(n) = V(n-1) - I_b(n-1) * Z_b(n-1) \quad \text{---------- (3)}$$

$$\text{where } n = 2, 3, \ldots Nn$$

Check the error between the present voltage values and previous voltage values and if the error is within limits stop the iterations, otherwise continue the same process with the obtained voltages.

Find the total Real and Reactive Power loss given by eqns.(4 & 5).

Real Power Loss is given by

$$P = \Sigma_{n=1}^{Nb} |I_b(n)|^2 \times R_b(n) \quad \text{----------- (4)}$$

Reactive Power Loss is given by

$$Q = \Sigma_{n=1}^{Nb} |I_b(n)|^2 \times X_b(n) \quad \text{----------- (5)}$$

3. Distributed Generation (DG):

The minimization of losses in Distribution system is very important because of the modernization of the distribution system through computer automation which requires most efficient operating scenario. In order to reduce these distribution losses DGs can be placed in the distribution system. The advantage of these DGs is reduction in real power loss, reactive power loss, improvement in the voltage profile etc.

The extent of these benefits can be achieved only through proper location and size of the DG. There are many methods of finding optimal location of DG like sensitivity analysis[14], loss sensitivity factor[16], V index[15] etc and the proposed DPSO method is compared with K. Vinoth kumar and M.P. Selvan sensitivity analysis[14].

Assumptions for the placement of DG:

1) DG injects only real power.
2) The total DG capacity is limited to 30% of the total load demand.
3) DG location is not considered at the slack bus.
4) Maximum numbers of DGs are limited to 3.

3.1 Problem Formulation:

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The objective function for this algorithm aims to minimize the total power losses in the distribution system along with voltage profile improvement.

ObjectiveFunction:

$$\min\ F_{total} = k_v f_v + k_p f_p + k_q f_q$$

where

$$\min\ f_v = \frac{\Sigma_{n=1}^{N_n} |V(n) - V(n,ref)|}{\Sigma_{n=1}^{N_n} |V(n,noDG) - V(n,ref)|}$$

$$\min\ f_p = \frac{\Sigma_{n=1}^{N_b} P_{Loss}^{withDG}(n)}{\Sigma_{n=1}^{N_b} P_{Loss}^{withoutDG}(n)} \quad \text{---- (6)}$$

$$(\text{where } P_{Loss} = R_b \times I_b^2)$$

$$\min\ f_q = \frac{\Sigma_{n=1}^{N_b} Q_{Loss}^{withDG}(n)}{\Sigma_{n=1}^{N_b} Q_{Loss}^{withoutDG}(n)}$$

$$(\text{where } Q_{Loss} = X_b \times I_b^2)$$

k_v, k_p, k_q are the weighting factors.

System constraints:

Voltage limits:

$$V_{min} \le V(n) \le V_{max} \quad \text{where } n = 1,2,3,\ldots.N_n$$

DG limits:

$$P_{DG}^{min}(n) \le P_{DG}(n) \le P_{DG}^{max}(n) \quad \text{where } n = n_1^{DG}, n_2^{DG}, n_3^{DG}$$

$$\text{such that } P_{DG_1} + P_{DG_2} + P_{DG_3} = P_{DG\,max}$$

4. Implementation of Discrete PSO for DG Placement

4.1. Overview of the DPSO

DPSO simulates the behaviours of bird flocking. Suppose the following scenario: a group of birds are randomly searching food in an area. There is only one piece of food in the area being searched. All the birds do not know where the food is. But they know how far the food is in each iteration. So what's the best strategy to find the food? The effective one is to follow the bird, which is nearest to the food. DPSO learned from the scenario and used it to solve the optimization problems. In DPSO, each single solution is a "bird" in the search space. We call it "particle". All of particles have fitness values, which are evaluated by the fitness function to be optimized, and have velocities, which direct the flying of the particles. The particles fly through the problem space by following the current optimum particles.

The DPSO define each particle as a potential solution to a problem. The position of i[th] particle of the swarm can be represented as

$$X_i = (X_{i1}, X_{i2}, \ldots\ldots\ldots\ldots X_{iN}) \quad \text{----- (7)}$$

Each particle also maintains a memory of its previous best position, represented as

$$P_i = (P_{i1}, P_{i2}, \ldots\ldots\ldots P_{iN}) \quad \text{----- (8)}$$

A particle in a swarm moves; hence, it has a velocity which can be represented as

$$V_i = (V_{i1}, V_{i2}, \ldots\ldots\ldots\ldots V_{iN}) \quad \text{----- (9)}$$

Each swarm in the structure of swarm population is considered as M×N matrix. In this matrix M represents the number of agents (population size) and N represents the number of particle is each agent.

$$V_i^{k+1} = K\ \ V_i^k + C_1 rand_1 \times\ Pbest_i^k - X_i^k + C_2 rand_2 \times\ Gbest^k - X_i^k \quad \text{---- (10)}$$

where

V_i^k	Velocity of individual i at iteration k
K	Construction factor
C_1, C_2	Weight factors
$rand_1$, $rand_2$	Random numbers between [0,1]
X_i^k	Position of individual i at iteration k
$Pbest_i^k$	Best position of individual i up to iteration k
$Gbest^k$	Best position of the group up to iteration k

Each individual moves from the current position to the next one by using the modified velocity.

$$X_i^{k+1} = \text{round}\ \ X_i^k + V_i^{k+1} \quad \text{----- (11)}$$

The search mechanism of the DPSO using the modified velocity and position of individual based on eqns. (10) and (11) is illustrated in Figure.2.

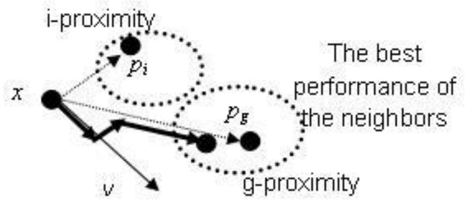

Fig.2. The search mechanism of the DPSO

4.2 Velocity update

To modify the position of each individual, it is necessary to calculate the velocity of each individual in the next stage. In this velocity updating process, the values of parameters such as k, C_1, C_2 should be determined in advance.

The construction factor,

$$k = \frac{2}{2 - j - \sqrt{j^2 - 4j}} \quad \text{and} \quad j = C_1 + C_2 \qquad \text{----- (12)}$$

The values of C_1 and C_2 have the same value, which implies the same weights are given between Pbest and Gbest in the evolution processes.

4.3 Update of Pbest and Gbest

The Pbest of each individual i at iteration k is updated as follows

$$\begin{aligned} Pbest_i^k &= X_i^k && \text{if } f_i^k > f_i^{k-1} \\ Pbest_i^k &= Pbest_i^{k-1} && \text{otherwise} \qquad \text{----- (13)} \\ Gbest_i^k &= best(Pbest_i^k) && \end{aligned}$$

where f_i, the objective function or fitness function is to be evaluated at the position of individual i. Gbest at iteration k is set as the best evaluated position among $Pbest_i^k$.

4.4 Stopping criteria

The DPSO is terminated if the iteration approaches to the predefined maximum number of iterations.

4.5 Flow chart for DG Optimal Location

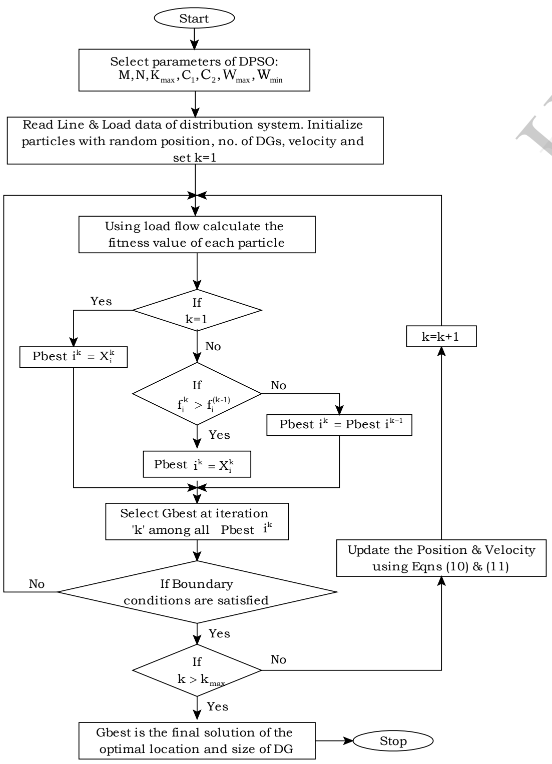

Fig.3 Flow chart for DG placement

5. Results and Analysis

The effectiveness of the proposed method is illustrated with two test systems consisting of 33-node and 69-node RDS. For the positioning of DG, the number of DGs is varied from one to three and the size of the DG is multiples of 50KVA. DPSO is used to find the optimal location of DG and size of the DG. The optimal location and size for the placement of DG is compared with the sensitivity analysis VSI [14] with the reduction in real power loss and the improvement in voltage profile.

5.1 Example-1:

The proposed algorithm is tested on 33-node radial distribution system whose single line diagram is shown in Fig.4. The variation of real power loss from one, two and three DG's are shown in Fig.5. The variation of reactive power loss from one, two and three DG's are shown in Fig.6. The variation of voltage profile by placement of one, two and three DG's are shown in Fig.7.

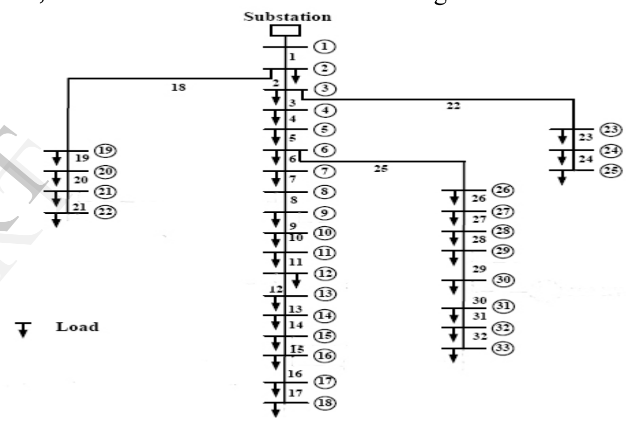

Fig.4 33-node RDS

The summary of results is shown in Table-1. The results are compared with [14] which are obtained by sensitivity analysis to identify the nodes and GA for the placement of DG. The results are shown that by placement of one DG the real power losses reduced from 144.1389KW to 125.5972KW with improvement of 9.164% and voltage regulation has varied from 1.872% to 2.22%, by placement of two DG's the real power losses reduced from 140.8153KW to 106.1180KW with improvement of 17.15% and voltage regulation has varied from 1.88% to 4.08%, by placement of three DG's the real power losses reduced from 108.0969KW to 105.4491KW with improvement of 1.309% and voltage regulation has varied from 4.070% to 4.082%.

Table.1 Summary results of 33-node RDS with DG's

Aspect	Without DG	One DG		Two DGs		Three DGs	
		VSI/GA[14]	DPSO	VSI/GA[14]	DPSO	VSI/GA[14]	DPSO
Node No	-	18	12	17,18	15,32	17,18,33	14,17,32
Rating(1)-KVA	-	900	1100	17-800	15-500	17-400	14-300
Rating(2)-KVA	-	-	-	18-100	32-600	18-100	17-200
Rating(3)-KVA	-	-	-	-	-	33-600	32-600
Total-1100 KVA	-	900	1100	900	1100	1100	1100
Vmin (pu)	0.9131	0.9302	0.9334	0.9303	0.9504	0.9503	0.9504
Ploss (kw)	202.32	144.138	125.597	140.8153	106.1180	108.0969	105.4491
Qloss (kvar)	134.92	99.9537	83.7298	97.4054	70.1545	72.6670	69.5314
Time(sec)	-	8.6956	7.9464	8.3497	8.3754	8.5487	8.4569

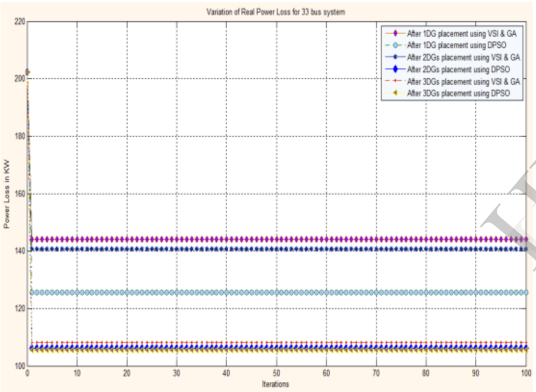

Fig.5 Variation of Real power loss 33-node RDS with DG's

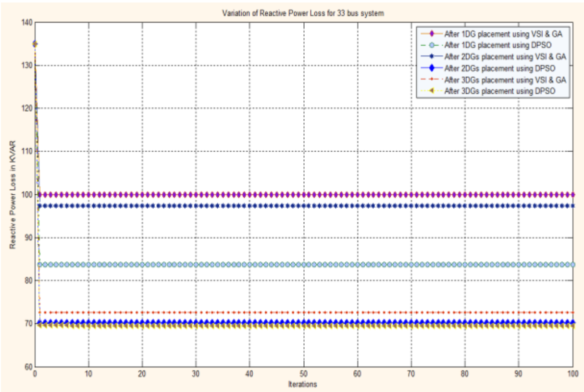

Fig.6 Variation of Reactive power loss 33-node RDS with DG's

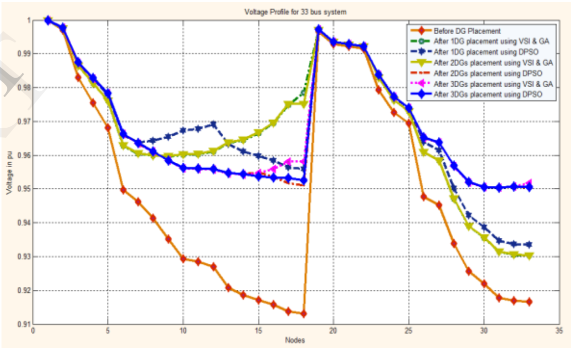

Fig.7 Voltage Profile of 33-node RDS with DG's

5.2. Example-2

The proposed algorithm is tested on 69-node radial distribution system whose single line diagram is shown in Fig.8. The variation of real power loss from one, two and three DG's are shown in Fig.9. The variation of voltage profile by placement of one,two and three DG's are shown in Fig.10.

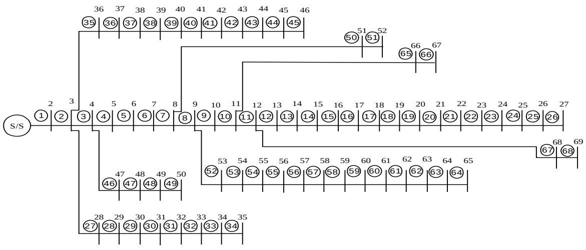

Fig.8 69-node RDS

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The summary of results is shown in Table-2. The results are compared with [14] which are obtained by sensitivity analysis to identify the nodes and GA for the placement of DG. The results are shown that by placement of one DG the real power losses reduced from 116.0737KW to 102.4029KW with improvement of 6.077% and voltage regulation has varied from 5.125% to 4.855%, by placement of two DG's the real power losses reduced from 107.0353KW to 101.7987KW with improvement of 2.33% and voltage regulation has varied from 5.165% to 5.063%, by placement of three DG's the real power losses reduced from 103.0896KW to 101.7719KW with improvement of 0.585% and voltage regulation has varied from 5.182% to 5.101%.

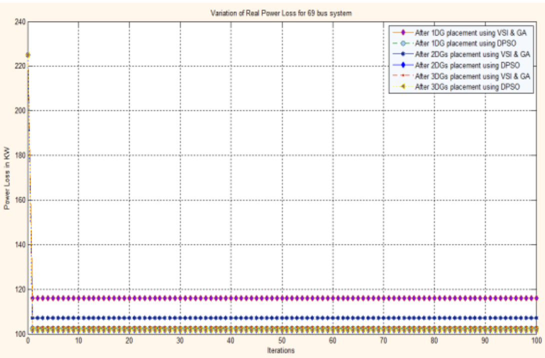

Fig.9 Variation of Real power loss 69-node RDS with DG's

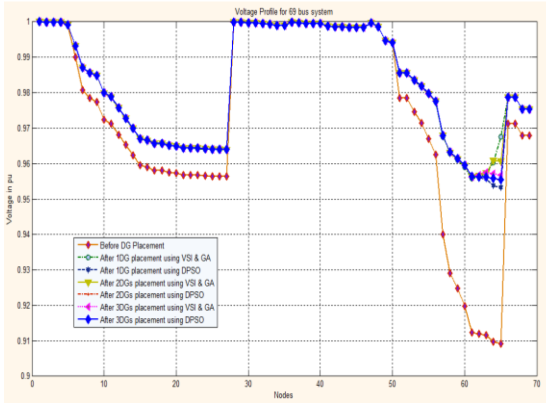

Fig.10 Voltage Profile of 69-node RDS with DG's

Table.2 Summary results of 69-node RDS with DG's

Aspect	Without DG	One DG		Two DGs		Three DGs	
		VSI/GA[14]	DPSO	VSI/GA[14]	DPSO	VSI/GA[14]	DPSO
Node No	-	65	61	64,65	61,64	63,64,65	61,64,65
Rating(1)-KVA	-	65-1150	61-1150	64-1100	61-850	63-850	61-850
Rating(2)-KVA	-	-	-	65-50	64-300	64-250	64-250
Rating(3)-KVA	-	-	-	-	-	65-50	65-50
Total-1150 KVA	-	1150	1150	1150	1150	1150	1150
Vmin(pu)	0.9091	0.9557	0.9533	0.9561	0.9552	0.9563	0.9555
Ploss(kw)	224.95	116.073	102.40	107.0353	101.79	103.08	101.77
Qloss(kvar)	102.1472	56.4442	49.5794	51.9056	49.2760	49.9240	49.2625
Time(sec)	-	27.0619	25.7261	26.3369	26.3802	27.1227	27.7273

6.Conclusion

DPSO for solving the DG placement in RDS has been proposed in this paper. This paper aims at discussing the reduction of real power loss and maintenance of voltage profile by using DG . The proposed method deals with optimal selection of nodes for the placement of DG and Size of the DG by using Discrete Particle Swarm Optimization (DPSO). From results the reduction of Real power loss and the improvement of voltage profile can be observed. Also that for the same capacity of DGs for single, two and three DGs the results are better if the number of DGs are more, especially the minimum voltage is improved if we have more number of DGs being total capacity same. The proposed algorithm is tested with two systems consisting of 33 node, and 69 node RDS. From the results, several important observations can be concluded as follows.

From the results, important observations can be concluded as follows.

- The power losses of distribution system can be effectively reduced by proper placement of DG.
- In addition of power loss reduction, the voltage profile can be improved.

References:

[1] M.E. Baran, and F.F. Wu, "Optimal capacitor placement on radial distribution system", *IEEE Trans. Power Delivery*, Vol. 4 (1), pp. 725 – 734, 1989.

[2] M.E Baran, and F.F. Wu, "Optimal sizing of capacitors placed on radial distribution system", *IEEE Trans. Power Delivery.*, Vol. 4 (1), pp. 735– 743, 1989.

[3] Srinivasan sundhararajan and Anil pahwa, "Optimal selection of capacitors for radial distribution systems using a genetic algorithm", *IEEE Trans Power System*, Vol. 9 (3), pp. 1499 – 1507, 1994.

[4] Y.C.Huang, H.T.Yang,, C.L.Huang, "Solving the capacitor placement problem in a radial distribution system using Tabu search approach",*IEEE Trans. Power System*, Vol. 11 (4), pp. 1868 – 1873, 1996.

[5] T. Ackermann, G. Anderson, and L.S. Soder, "Distributed generation: a definition", *Electric Power Systems Research*, Vol. 57 (3), pp. 195 –204, 2001.

[6] N. Jenkins, R. Allan, P. Crossley, D. Kirschen, and G.Strbac, "Embedded generation", The institution of electrical engineers, London, 2000, 1st edition

[7] G. Carpinelli, G. Celli, F. Pilo, A. Russo, "Distributed generation siting and sizing under uncertainty", IEEE Porto power tech proceedings, Porto, Portugal, Sept. 2001, 4, pp.1– 7

[8] A. Bhowmik, A. Maitra, S.M. Halpin, E. Schatz, Joe, "Determination of allowable penetration levels of distributed generation resources based on harmonic limit considerations", *IEEE Trans. Power Delivery*, Vol. 18 (2), pp. 619 – 624, 2003.

[9] T. Niknam, A.M. Ranjbar, A.R. Shirani, "Impact of distributed generation on Volt/Var control in distribution networks", IEEE Bologna power tech conference, Bologna, Italy, June 23-26, 2003, pp.1 – 7.

[10] G.W. Ault, J.R. McDonald, and G.M. Burt, "Strategic analysis framework for evaluation distributed generation and utility strategies", IEE Proc. Generation, Transmission, Distribution, Vol. 150 (4), pp.475 – 481, 2003.

[11] M.E. Hamedani Golshan, and S.A. Arefifar, "Distributed generation, reactive sources and network-configuration planning for power and energy-loss reduction", IEE Proc. Generation, Transmission,Distribution, Vol.153 (2), pp.127 – 136, 2006.

[12] J. Kennedy and R. Eberhart, "Particle Swarm Optimization", Proceedings of IEEE International Conference on Neural Networks (ICNN'95), Vol. IV, pp.1942-1948, Perth, Australia, 1995.

[13] J. Kennedy ,R. Eberhart, "A new optimizer using particle swarmtheory," Proc. 6th Int. Symposium on Micro Machine and Human Science, pp. 39-43, 1995.

[14] K. Vinoth kumar and M.P. Selvan , "Planning and Operation of Distributed Generations in Distribution Systems for Improved Voltage Profile ", 2009 IEEE , pp.1 – 7, 2009.

[15] J. B. V. Subrahmanyam, C. Radhakrishna "Distributed Generator Placement and Sizing in Unbalanced Radial Distribution System ", International Journal of Electrical and Electronics Engineering, Vol.3, pp.746 – 753. 2009

[16] Satish Kansal1, B.B.R. Sai, Barjeev Tyagi, and 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

[17] K. Vinoth kumar and M.P. Selvan , "A Simplified Approach for Load Flow Analysis of Radial Distribution Network ", International Journal of Computer and Information Engineering Vol 2 No 4 ,2008,pp 272-283

[18] M.Chakravorty, D.Das, "Voltage Stability analysis of radial distribution networks", International Journal of Electrical Power and Energy Systems, Vol.23(2),pp129-135,2001