The Better Optimization Technique for the Placement of DG In Order To Reduce Overall Cost of Power System

Subin Sunny, P.Balaji

Abstract— In a radial distribution system, the voltages at buses decrease and losses increase with increasing distance from the substation. DG can be utilized to overcome these problems. DG can deliver a portion of real and/or reactive power for reducing feeder current and thus improving both voltage profile and transmission efficiency. However, studies also shows incorrect placement of DG would lead to higher losses than the losses without DGs. This paper focuses on maximizing the net saving by minimizing the energy loss cost while considering installation and running cost of the Distributed generators. Both GA and PSO algorithms are used to find the optimal locations and sizes of DG. The obtained results are discussed and compared to each other. The proposed method is programmed and tested in a 33 bus distribution system using MATLAB software. For load flow analysis of the distribution network, forward backward sweep algorithm is used.

Index Terms— Voltage Profile Improvement, Genetic Algorithm, Particle Swarm Optimization, Distribution Generators, Forward/Backward Sweep Algorithm.

I. INTRODUCTION

Energy deficiency is the major issue faced by developing countries due to financial problems. It occurs when the available supply is less than the load demand. Power cut and load shedding are the only solutions we have in order to balance both supply and demand. Around 15-20% of the total generated power generation is lost between source and load due to transmission and distribution losses. Unleashing the energy loss occurring during transmission can help to reduce the energy deficiency to some extent. It has been established that 70% of the total losses occur in the distribution system due to its low X/R ratio and low voltage operation. There are several techniques for minimizing the distribution losses such as Feeder reconfiguration, Reinforcement of the feeder, Grading of conductor, Construction of new substation, Reactive power compensation, Optimal placement of DG etc. Because of the increasing popularity of DG, it is utilized in this paper for minimizing losses. Studies show that up to 70% of the losses can be minimized by the proper placement DGs of optimal size at the right locations.

DG is a small generating unit based on the non-renewable or renewable energy connected to the distribution side of the power system with capacity ranging from a few kilowatts to up to several megawatts. In a radial network due to line drop, voltage decreases with increasing distance from the substation. Placing DG can compensate this voltage drop and thus improve the power quality which in turns improves efficiency and performance of equipments connected to the system.

The high R/X ratios of branches in a distribution system compared to a transmission system makes the distribution system ill conditioned. Therefore using conventional methods like Newton Raphson (NR) and fast decoupling cannot be effectively used in radial distribution system for load flow analysis. So for the load flow analysis of the given distribution network, backward and forward sweep algorithm is used. It can exploit the radial nature of the distribution system and it is computationally more efficient. Another advantage of the proposed method is that all the necessary data can be stored in vector form, thus saving a lot of computer memory. Convergence is always guaranteed for any type of practical radial distribution network with realistic R/X ratios while using the sweep technique.

The objective of this work is to find out the location and sizes of the DG so as to maximize the net saving by minimizing the energy loss cost for a given period of time with single DG, double DGs, and 3 DGs. The installation cost and unit energy generation cost of DG also taken into account. The following assumptions are considered for DG placement.

1) The sizing and location of DG is considered at the peak load only.
2) Maximum active power limit of DG for different test systems is assumed to be equal to the total active load of the system.
3) The lower and upper voltage thresholds for DG with the optimal size, location and power factor are set at 0.95–1.05 pu.

Both PSO and GA are used for finding the optimal places of DGs and the results are compared and discussed.

II. PROBLEM FORMULATION

The objective is to maximize the net saving considering the costs of distribution generation at the same time minimize losses and improve voltage profile for a period of one year.

A. *Objective Function*

The objective function consists of two main terms: energy loss cost and distributed generation cost.

- **Energy loss Cost (EL_C):**

$$EL_C = (EC * GE) \quad (1)$$

Where,

$$EL = [\, P_{Li} \,] * t \quad (2)$$

t = number of hours in the given time period

P_L = power loss in KW

GE=energy loss rate in $/KWhr

- **DG Cost (DG_C):**

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It consists of
1) Installation cost
2) Variable cost

$$DG_C = \left(\sum_{i=1}^{NDG} GI_C\right) + \left(\sum_{i=1}^{NDG}(P_{DG\,i} * DG_R)\right) \qquad (3)$$

Where,

P_{DG} = power generated from DG in KW
DG_R = Rate of DG/KW
GI_C= DG installation cost

- **Total Cost**

Totalcost = ELs + DG_C (4)

% Net saving = (Energy loss cost without DG – (Energy loss cost with DG + DG_C))/ (energy loss cost with DG)

B. Operational Constraints:

Constraint I: Bus voltages

From the point of view of system stability, power quality etc., each bus voltage (V_i) must be maintained around its nominal value ($V_{i\,nom}$) within a permissible voltage band, specified as [$V_{i\,min}$, $V_{i\,max}$].

Where,

$V_{i\,min}$ is the minimum permissible value of voltage at bus i
$V_{i\,max}$ is the maximum permissible voltage at bus i.

This can be mathematically described as:

$$V_{i\,min} \le V_i \le V_{i\,max} \qquad (5)$$

Constraint II: The DG capacities

The capacity of each DG ($P_{DG\,i}$) should also be varied around its nominal value. Hence each P_{DG} must also be maintained within a permissible band, specified as [$P_{DG\,min}$, $P_{DG\,max}$], where $P_{DG\,min}$ is the minimum permissible value of each DG capacity and $P_{DG\,max}$ is the maximum permissible value of each DG capacity. This should be a mandatory requirement because e.g. if a DG capacity is less than the specified minimum value, then the type and cost of the corresponding DG should also be varied. The DG capacity limit is given as,

$$P_{DG\,min} \le P_{DG} \le P_{DG\,max} \qquad (6)$$

III. BACKWARD AND FORWARD SWEEP ALGORITHM

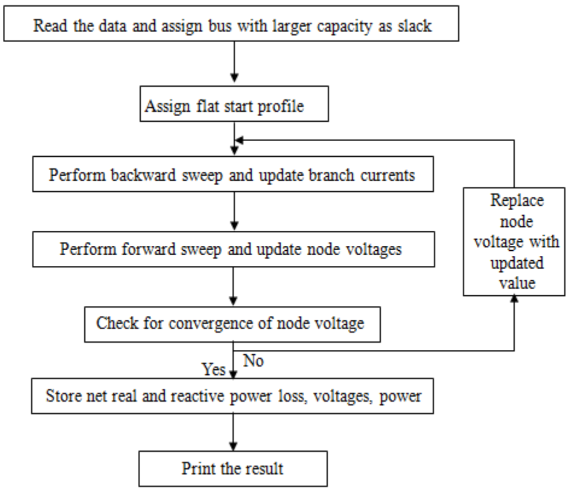

Fig. 1: Backward and Forward Sweep Algorithm

This method is a simple and efficient method. The node voltages and branch currents are evaluated directly from KVL and KCL respectively. The method converges fast and the results are highly accurate. Backward sweep calculates the branch currents. As an initial step, flat voltage profile has been assumed. At the end of each backward sweep updated list of branch currents are saved. The forward sweep calculates the node voltages. Backward and forward sweeps are repeatedly done with the updated values as initial values till the convergence limit reached. At the end of each backward sweep updated list of branch currents are saved. With that the forward sweep calculates the node voltages as follows

$$Vj = Vi + Iij\ Zij \qquad (7)$$

Backward and forward sweeps are repeatedly done with the updated values as initial values till the convergence limit reached. This has been shown in the figure 1 as flow chart. The total real power loss in power systems is represented by

$$P_{Loss} = ((V_i - V_j) / R_{ij})^{2} * R_{ij} \qquad (8)$$

The total reactive power loss in power systems is represented by

$$Q_{LOSS} = ((V_i - V_j) / R_{ij})^{2} * X_{ij} \qquad (9)$$

IV. GENETIC ALGORITHM

Genetic algorithm mimics Darwin's theory of survival of the fittest and process of natural evolution to find the optimal solution for a problem. It was first introduced by John Holland of University of Michigan in 1970. The genetic algorithm starts with no knowledge of the correct solution and depends entirely on responses from its environment and evolution operators such as reproduction, crossover and mutation to arrive at the best solution. The steps for optimization using genetic algorithm is shown below.

Step 1: Randomly generate initial population strings.

Step 2: Calculate the fitness value for each string in the population and select the fittest members of the population.

Step 3: Reproduce using a probabilistic method (e.g. roulette wheel).

Step 4: Create the pool after selection.

Step 5: Create offspring through crossover and mutation operation.

Step 6:`Evaluate the offsprings and calculate the fitness value for each solution.

Step 7: If the search goal is achieved, or an allowable generation is attained, return the best chromosome as the solution; otherwise go to step 4.

The probabilistic method chosen here is roulette wheel due to its simplicity and the crossover technique used is arithmetic crossover mechanism with crossover probability from 0.8 to 1. The mutation probability is set between 0.5 to 1. The maximum iteration is set at 100 while population size is 20.

V. PARTICLE SWARM OPTIMIZATION (PSO)

In 1987 a biologist named Craig Reynolds derived a formula by observing the social behavior of animals like flock of birds or school of fishes. Based on this theory J. Kennedy and R. C. Eberhart introduced an optimization technique called particle swarm optimization. Like GA, PSO also begins with random initialization of solutions called particles. These particles move around the search space with a constant velocity based on the social psychological tendency of individuals to emulate the success of other individuals. The change to a particle within the swarm is therefore influenced by the experience, or knowledge, of its neighbours. In order to find the optimal place of DG using PSO, initial populations are generated randomly with random position and size of DG in the search space (or given distribution network).

Each particle (or DG position) is then checked with different operational constraints before evaluating the net cost using equation (4). If the particle is not satisfying the constraints, it is considered as in feasible. After that each particle is compared with previous individual best and the better one is stored as Pbest along with corresponding particle position. Then from Pbest of all particles, overall best is stored as Gbest. Then the velocity and position of particle is updated and particles are compared to get the current Pbest and Gbest. This procedure is continued until the maximum iteration limit is reached.

Fig. 3: Voltage profile of the 33-bus system without DG units

VI. CASE STUDY

No	No. of DG	Power Loss KW		DG Location		Size of DG KW		Total Energy Cost $/year		Net Saving %	
		GA	PSO	GA	PSO	GA	PSO	GA	PSO	GA	PSO
1	0	181.968		-		-		159400		-	
2	1	89.95	89.95	31	31	1100	1100	111301	111301	30.17	30.17
3	2	43.33	41.58	14 31	14 31	1050 850	1100 850	95457	95178	40.11	40.29
4	3	35.35	35.47	14 30 32	14 30 32	750 700 650	750 600 750	98481	98578	38.22	38.15

Table I: Comparison of Simulation Results: GA vs. PSO

In this work, the optimal location and size of the DGs are studied using IEEE 33-bus radial distribution system shown in Fig.2. In all calculations the following test parameters are used. The base values are taken as 100kva and 23kv. The installation cost per DG is 5000$ with a total running cost of 0.01$/ kwh.

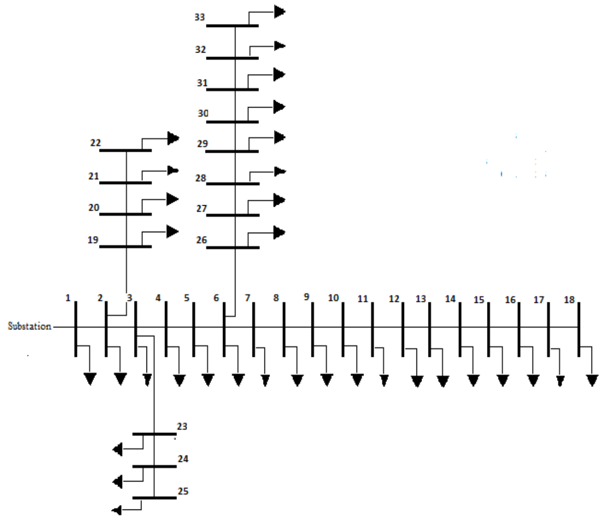

Fig. 2: 33-bus IEEE distribution network

Fig.3 & 4 show the voltage profile (in p.u.) of the IEEE 33-bus radial distribution system without and with DGs connected to it. We can see an improvement in voltage profile with increasing number of DGs.

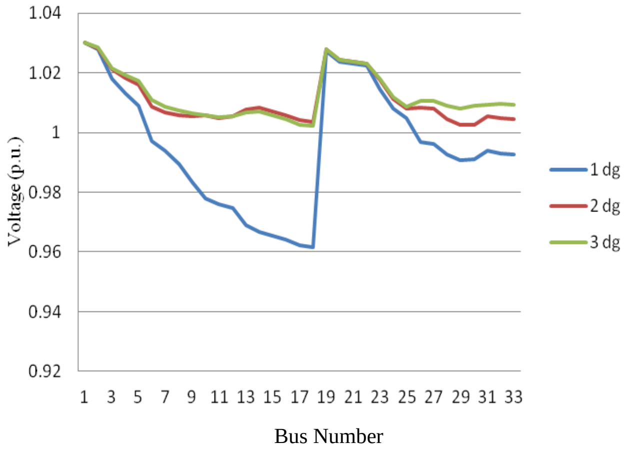

Fig. 4: Voltage profile of the 33-bus system with DG units

Table I shows the results (best location, DG sizes, loss, DG cost and net profit) with both GA and PSO. Also shows the power loss of the system (without DG and with DG). The execution time for both GA and PSO is shown in fig 5.

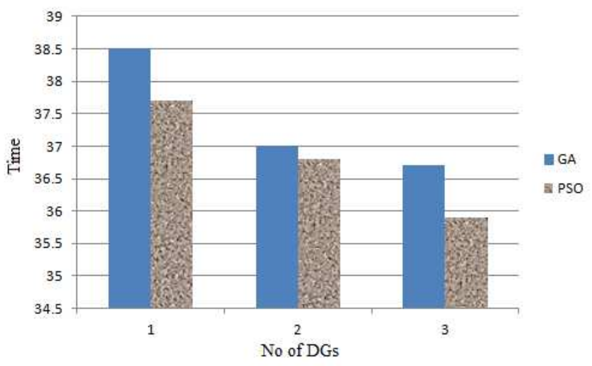

Fig. 5: Execution time

VII. CONCLUSION

The DG placement has been studied in an IEEE 33-bus radial distribution system. Load flow analysis of the radial distribution system is carried out using forward and backward load flow method. The buses for placement of DG are determined by considering the energy loss cost. Optimization improves voltage profile and transmission efficiency by mitigating total power loss and total energy cost in the radial distribution system. The overall cost of the system with DG considering installation cost and energy rate is found to be less than the distribution system without DG.

The best saving using PSO optimisation technique is found to be 40.29% compared to the 40.11% of GA. PSO also showed a better 1.75kW reduction in power loss compared to GA. The execution times of GA show a lag of 02. to 0.8 second in comparison with PSO. From all these results we can conclude PSO is a better algorithm technique than GA in every way for the overall cost reduction of the power system containing DGs.

REFERENCES

[1] G. Pepermans, J. Driesen, D. Haeseldonckx, R. Belmans and W.D.haeseleer, 2005. “Distributed Generation: Definition, Benefits and Issues”, Energy Policy, 33: 787-798.

[2] W. El-Khattam, and M.M.A. Salama, “Distributed Generation Technologies, Definitions and Benefits”, Electric Power Systems Research. 71, pp.119–128, 2004.

[3] S. Ghosh , S.P. Ghoshal and S. Ghosh, “Optimal sizing and placement of DG in network system”, International Journal of Electrical Power and Energy Systems. 2010, 32 (8): 849-856.

[4] C´Urcˇ Ic´ S., Strbac G. and Zhang X.-P.: “Effect of losses in design of distribution circuits□, IEE Proc., Gener. Transm. Distrib, 2001, 148, pp. 343–349.

[5] Singh RK and Goswami SK. “Optimum allocation of distributed generations based on nodal pricing for profit, loss reduction, and voltage improvement including voltage rise issue,” Electrical Power Energy System 2010; 32:637–44.

[6] K. Varesi, “Optimal Allocation of DG Units for Power Loss Reduction and Voltage Profile Improvement of Distribution Networks using PSO Algorithm,” World Academy of Science, Engineering and Technology 60 2011.

[7] Sun jian, Jiang Daozhuo and Liu Zhihua, “Modified power flow algorithm of distribution network based on forward/backward sweep method,” Electric Power Automation Equipment.2004 , 24 (3) :81-84

[8] A. A. Bagheri, A. Habibzadeh and S. M. Alizadeh, “Comparison of the Effect of Combination of Different DG Types on Loss Reduction Using APSO Algorithm,” Canadian Journal on Electrical and Electronics Engineering Vol. 2, No. 10, October 2011.

[9] Naresh A, “An analytical approach for DG allocation in primary distribution network," Electric Power and Energy Systems, pp. 669-678 (2006).

[10] Caisheng Wang and M. Hashem Nehrir, “Analytical Approaches for Optimal Placement of Distributed Generation Sources in Power Systems,” IEEE Transactions on Power Systems, Vol. 19, No. 4, pp. 2068 – 2076, November 2004.

[11] Víctor H. Méndez Quezada, Juan Rivier Abbad and Tomás Gómez San Román, “Assessment of Energy Distribution Losses for Increasing Penetration of Distributed Generation,” IEEE Transactions on Power Systems, Vol. 21, No. 2, pp. 533- 540, May 2006.

[12] W. Prommee and W. Ongsakul, “Optimal Multi- Distributed Generation Placement by Adaptive Weight Particle Swarm Optimization,” Proc. Of the IEEE International Conference on Control, Automation and Systems, pp 1663-1668, Oct. 2008.

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