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**ORIGINAL ARTICLE**

# Optimal Placement Distributed Generation by genetic algorithm to Minimize Losses in Radial Distribution Systems

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**ABSTRACT**
*Distributed Generation (DG) is a promising technology to many power system problems such as voltage regulation, power loss, etc. Genetic Algorithm optimizes the placement Distributed Generators in radial distribution systems to minimize the total power loss and also to improve the voltage sag performance.DGs may be placed at any load buses. The proposed method determines which load buses are to have DGs and of what sizes they are respectively. Load flow algorithm and three phase short circuit analysis are combined appropriately with GA, till access to acceptable results of this operation. The suggested method is programmed under MATLAB software. In GA randomly generates initial population, find network losses and bus voltages of each population member by means of power flow calculations, keep the member with the best configuration as a reference and re-generate the new population for the next iteration based on the current population and based on the reference.*
***Keywords:****Unbalance radial distribution system, power losses, voltage profile, Quantum GA*

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## INTRODUCTION
The growth of electricity demand is increasing rapidly. DG is one of the better alternatives to fulfill this ever growing energy demand. DG units (also called decentralized generation, dispersed generation, and embedded generation) are small generating plants connected directly to the distribution network or on the customer site of the meter. Integration of Distributed Energy Resources (DER) with distribution network offers a promising solution; therefore, an intensive level of research is needed to understand the impacts of distributed resources on Distribution System. In the last decade, the penetration of renewable and nonrenewable distributed generation (DG) resources is increasing worldwide encouraged by national and international policies aiming to increase the share of renewable energy sources and highly efficient micro-combined heat and power units in order to reduce greenhouse gas emissions and alleviate global warming. Distributed or dispersed generation (DG) or embedded generation (EG) is small-scale power generation that is usually connected to or embedded in the distribution system. The term DG also implies the use of any modular technology that is sited throughout autility‟s service area (interconnected to the distribution or sub-transmission system) to lower the cost of service [1]. Next to environmental advantages, DGs contribute in the application of competitive energy policies, diversification of energy resources, and reduction of on-peak operating cost, deferral of network upgrades, lower losses and lower transmission and distribution costs, and potential increase of service quality to the end-customer. Moreover, it reduces system energy loss, alleviates transmission congestion, improves voltage profile, enhances reliability and provides lower operating cost. Because of small size compared with conventional generation units, DG is more flexible to install in terms of investment and time. Moreover, DGs are available in modular units, characterized by ease of finding sites for smaller generators, shorter construction times, and lower capital costs. Decision about DG placement is taken by their owners and investors, depending on site and primary fuel availability or climatic conditions.
The benefits of DG are numerous [2, 3] and the reasons for implementing DGs are an energy efficiency or rational use of energy, deregulation or competition policy, diversification of energy sources, availability of modular generating plant, ease of finding sites for smaller generators, shorter construction times and lower capital costs of smaller plants and proximity of the generation plant to heavy loads, which reduces transmission costs. Before operating distributed and dispersed generation in power system, different technical, environmental, commercial and regulatory issues should be analyzed properly. Most significant technical

barriers are protection, power quality, stability and islanding operation. However, there are some other issues which should be analyzed before to maximize these technical benefits. Also it is accepted by many countries that the reduction in gaseous emissions (mainly CO2) offered by DGs is major legal driver for DG implementation [4]. Therefore, detail and exact analysis method is required to determine the proper location and size of DG more accurately and precisely. In distribution system,DG should be allocated in an optimal way such that it will reduce system losses and hence improve voltage profile [3].

The distribution planning problem is to identify a combination of expansion projects that satisfy load growth constraints without violating any system constraints such as equipment overloading [5]. Significant risks are associated in connecting such equipment directly to utility distribution system. The insulation level of the machines may not synchronize with the system. Therefore, direct connection of DG is often discouraged [4]. Distribution network planning is to identify the least cost network investment that satisfies load growth requirements without violating any system and operational constraints. Due to their high efficiency, small size, low investment cost, modularity and ability to exploit renewable energy sources, are increasingly becoming an attractive alternative to network reinforcement and expansion. Numerous studies used different approaches to evaluate the benefits from DGs to a network in the form of loss reduction, loading level reduction [6-8]. In our study, we will try to focus on optimum location and size of DG to decrease total system power loss. In most of the previous researches of DG sizing and allocation, DG has been connected with grid directly.

Naresh Acharya et al suggested a heuristic method in [9] to select appropriate location and to calculate DG size for minimum real power losses. DGs to solve network problems has been debated in distribution networks, the fact is that, in most cases, the distribution system operator (DSO) has no control or influence about DG location and size below a certain limit. Though the method is effective in selecting location, it requires more computational efforts. The optimal value of DG for minimum system losses is calculated at each bus. Placing the calculated DG size for the buses one by one, corresponding system losses are calculated and compared to decide the appropriate location. More over the heuristic search requires exhaustive search for all possible locations which may not be applicable to more than one DG. This method is used to calculate DG size based on approximate loss formula may lead to an inappropriate solution.

## LITERATURE REVIEW

Generally, Distributed generation means the electric power generation within distributed network to fulfil the rapid energy demand of consumers. However, distributed generation can be defined in a variety of ways.

1) The Electric Power Research Institute (EPRI) defines distributed generation as generation from 'a few kilowatts up to 50 MW' [5].

2) International Energy Agency (IEA) defines distributed generation as generating plant serving a customer on-site or providing support to a distribution network, connected to the grid at distributed level voltages [6].

3) The International Conference on large High Voltage Electric Systems (CIGRE) defines DG as 'smaller than 50-100 MW' [5].

Although there are variations in definitions, however, the concept is almost same. DG can be treated as small scale power generation to mitigate the consumer energy demand. Distributed Generation can come from a variety of sources and technology. To analysis the DER impacts, different types of 'generator groups' can be considered [7]. Here, we will consider induction generator as distributed generation source for our analysis purpose.

As the technical design of each distribution network is unique, therefore, it can not be answered what should be the optimum generation capacity or rating of DG [5]. The maximum size or rating of DG which can be connected to a distribution network depends on numerous factors, such as voltage level within the distribution system, power loss profile and other technical, environmental, commercial and regulatory issues. In our paper, we will focus on the technical issues only. As DG offers lots of benefit, the penetration of DG in distribution system is increasing rapidly. Therefore, DG should be allocated in an optimal way to maximize the system efficiency.

In a distribution system power loss varies with numerous factors. Real power losses of a distribution system depend on the resistance of distribution lines, core losses of transformers and motors. As dielectric and rotational losses are so small compared with line losses, therefore, only line losses are considered in this analysis. The complex power $S_{ij}$ from node
i to j and $S_{ji}$ from node j to i are

$$S_{ij} = V_i I_{ij}^{*}$$

$$S_{ji} = V_j I_{ji}^{*}$$

Where, $V_i$ and $V_j$ are the voltages at node i and j respectively.

The line current $I_{ij}$ which is measured at bus i in the positive direction of i to j and $I_{ji}$ which is measured at bus j in the positive direction of j to i. Therefore, power loss in any line between node i and j can be written as the algebraic sum of power flows determined from (1) and (2) [8].

$$S_{Lij} = S_{ij} + S_{ji}$$

After any converged load flow, power loss in any line can be calculated using (3) and taking the summation of all line losses, total power loss of the network can be calculated using equation (4) where n is the number of lines.

$$Loss = \sum_{k=1}^{n} S_L(k)$$

For any distribution system, placement of any DG unit will change the power loss profile of that system. Actually, in distribution network, power loss curve with the variation of power generation at a particular location is approximately quadratic function because Line Losses $\propto I^2$R and I $\propto$ Considering I is the line current, R is the resistance, and S is the apparent power flowing through the line [9]. Therefore, as the DG size is increased in any location of a power distribution network, the total system losses are reduced to a minimum value. With further increasing of DG, losses again start to increase. This trend of losses with DG size variation is given in Fig. 1 for a test case to demonstrate the sizing and location issues of DG. Here, for DG size PDG2 we get the minimum power loss which is called optimum DG size for that bus.

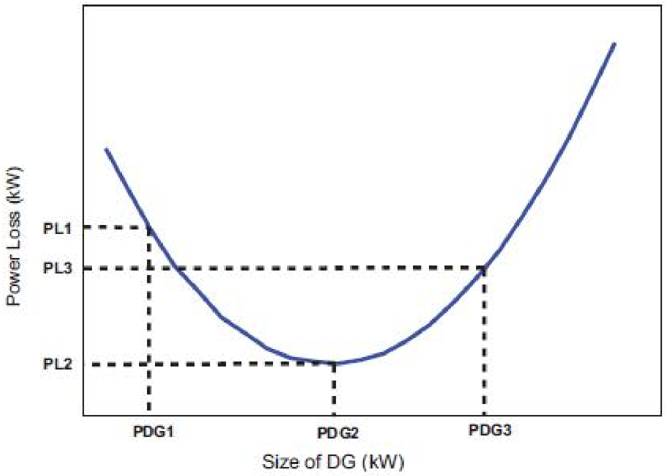


Fig. 1. Power loss characteristic of distribution system with DG size variation

Actually, the structure of distribution system is such that power should flow from the substation to the consumer end and conductor sizes are also decreased gradually [3]. When a DG is placed in the network, it is desirable that power should be consumed within the distribution network and thus improves power profile. Any size of DG more than the optimum size will create reverse flow of power towards distribution substation. Therefore, excessive power flow through small sized conductors towards the transmission area will increase the power losing distribution network.

In the literature, genetic algorithm and PSO have been applied to DG placement [10-13].In all these works either sizing or location of DGs are determined by these methods. This paper presents a new methodology using Clonal selection algorithm[14-17] for the placement of DG in the radial distribution systems. The DG placement problem has therefore attracted the interest of many research efforts in the last fifteen years [1]–[83], since it can provide DSOs, regulators, and policy makers useful input for the derivation of incentives and regulatory measures. The Clonal algorithm is a new population based meta heuristic approach inspired by Clonal principle of immune system of human body. The advantage of this algorithm is that it does not require external parameters such as selection, cross over rate and mutation rate as in case of genetic algorithm and differential evolution and it is hard to determine these parameters in prior. The other advantage is that the global search ability in the algorithm is implemented by introducing hyper mutation which differs from mutation in GA in two ways. One is the mutation rate is very high that every solution is mutated here and the second one is the mutation is not a single bit mutation. The advantage of Clonal algorithm is its dynamic population size. However, DG placement impacts critically the operation of the distribution network.

Inappropriate DG placement may increase system losses and network capital and operating costs. On the contrary, optimal DG placement (ODGP) can improve network performance in terms of voltage profile, reduce flows and system losses, and improve power quality and reliability of supply. In this paper, the optimal locations of distributed generators are identified based on single DG placement method[18] and Clonal optimization technique which takes the number and location of DGs as input has been developed to determine the optimal size(s) of DG to minimize real power losses in distribution systems. The advantages of relieving Clonal method from determination of locations of DGs are improved convergence characteristics and less computation time. Voltage and thermal constraints are considered. The effectiveness of the proposed algorithm was validated using 33-Bus Distribution System [19].To test the effectiveness of proposed method; results are compared with different approaches available in the literature. The proposed method has outperformed the other methods in terms of the quality of solution and computational efficiency.

## MATERIAL AND METHODS

Several indices have been developed in literature to measure the impact of sag. These indices are not suitable for direct use in the DG placement problem. Number of customers affected due to the voltage sag may be a probable measure, but it is felt that KVA/MVA capacity of the loads disturbed due to sag would be a better indicator of the severity of the voltage sag as it would include both the number of customers and the effected loads.

The present paper attempts to solve the voltage sag magnitudes under fault condition performing simple short circuit analysis. The pre-fault voltages at different buses are considered to be 1 p.u. and loads are presented by their equivalent impedances. The fault impedance is assumed to be very less in the order of $10^{-6}$ p.u. Performing short circuit analysis the voltages are observed and those buses are identified which has voltage less than $V_{TH}$. Where $V_{TH}$ (0.85 pu here) is the threshold voltage below which the loads are disturbed due to voltage sag problem. Then the loads connected at those buses are added to get total load disturbed for that particular fault. This method is repeated for all the possible faults. For different DG locations the fault places are kept fixed.

Thus the total load disturbance for every location of DG presented in KVA or MVA will be considered as a measure of sag performance. For two DG also the same method is applied. In that case the system with a single DG is considered to be the base system.

The function that has to be minimized consists of two objectives:

·Minimize the active power losses:

Mathematically, the objective function can be written as:

$$\text{Minimize } P_L = \sum_{k=1}^{N_{SC}} Loss_K \quad \text{------------------------------ (1)}$$

K-different section

$N_{SC}$- number of section

- Minimize the load disturbed $S_{DIST}$

$$S_{DIST} = \sum_{i=1}^{N_F} LoadDist_i \quad \text{--------------------------- (2)}$$

$N_F$ is the number of faults; *Load Dist*is the load disturbed due to one fault.

• *Power flow balance equations: The* balance of active and reactive powers must be satisfied in each node:

• *Power flow limit:* The apparent power that is transmitted through a branch *l* must not exceed a limit value, $S_{lmax}$, which represents the thermal limit of the line or transformer in steady state operation:

$S_l$d”$S_{lm}$——————————————————-(3)

• *Bus voltages:* For several reasons (stability, power quality, etc), the bus voltages must be maintained around the nominal value:

$U_{i\,min}$ d”$U_{i\,nom}$ d”$U_{i\,max}$ ————————————-(4)

Generally, GA comprises three different phases of search:

Phase1: creating an initial population; phase 2: evaluating a fitness function; phase -3: producing a new population. GA optimizes a single variable, the fitness function. Hence, the objective function and some of the constraints of the problem at hand must be transformed into some measure of fitness.

*Encodings:* The design of chromosome is very simple in this problem. As only the location is to determine thus location of $DG_1$ and location of $DG_2$ from the two component vector as shown in figure-1.

| $DG_1$ | $DG_2$ |
|---|---|
| Position (bus number) | Position (bus number) |

Both the components can take values from 2 to N. Two DG always are placed in different location other than slack bus.

*Fitness Function:* This function measures the quality of chromosomes and it is closely related to the objective function. Objective function for this paper is computed from equation (1) and (2). The effect of constraints is included in the fitness function by checking separately and the violations are handled using a penalty function approach. The overall fitness function designed during the study is

$$f(x) = \frac{P_L}{P_{Bloss}} + \frac{S_{DIST}}{S_{Bdist}} - \xi \sum_{1}^{nr} bal_i - \varsigma \sum_{k=1}^{n} thermal_k - \mu \sum_{1}^{n} voltage_k \quad \text{-----------------} \ (5)$$

The complete MATLAB program consisting load flow algorithm, short circuit analysis and Genetic Algorithm for solving the DG placement problem can be written in the simplified form as below:

*BEGIN*
*Read network data*
*Run Newton Raphson load flow and store results for base case*
*Run short circuit analysis without DG to get the base case result*
*Encode network data*
*Set genetic parameters*
*Create initial population*
*While < stopping condition not met> execute*
*For each individual in current generation*
*Run power flow*
*Run short circuit analysis*
*Evaluate fitness*
*End For*
*Select (current_generation, population_size)*
*Crossover (selected_ parents, crossover_rate)*
*Mutation ( current_generation, mutation_rate)*
*Current_generation++*
*Endwhile*
*Show solution*
*End*

Roulette Wheel Selection, which chooses parents by simulating a roulette wheel with different sized slots, proportional to the individual's fitness, is chosen here. The one point and scattered crossover mechanisms were tested in this study. The crossover rate was set to 0.85. The mutation rate was set to 0.2. Initial population in this paper was generated randomly, with individuals within the bounds set for each independent variable of the problem.

## RESULT AND DISCUSSION

The proposed method is applied to a 33-bus, 11 KV radial feeder with lateral branches (figure-2). The details of the network and the load characteristics are provided in [7].

The total installed peak power demand of the system is 5.4MVA, with an average power factor of 0.85. The system has a power loss of 222 KW and minimum system voltage 0.947 pu observed at bus 27.

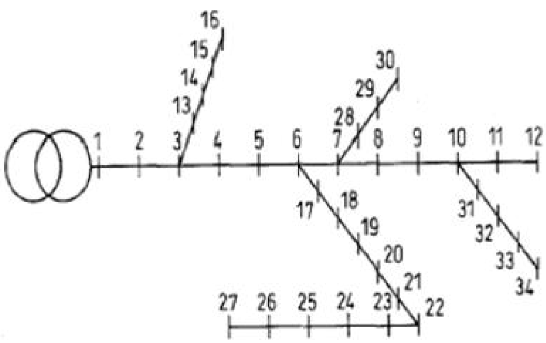

**Figure 2.single line diagram of a 33 bus radial system**

In this problem two DGs of capacity 1.5 MW and 0.4 MVAR are considered to be installed.

 

TABLE-I:
COMPUTATIONAL RESULTS WITH THE GENETIC ALGORITHM APPROACH

| No of DG units | Losses [KW] | Load disturbed [MVA] | Solution | | |
|---|---|---|---|---|---|
| | | | location | | size |
| Without DG | 222 | 169.462 | NA | NA | NA |
| 1 | 116.6 | 74 | 19 | NA | fixed |
| 2 | 45.5 | 46 | 24 | 7 | fixed |

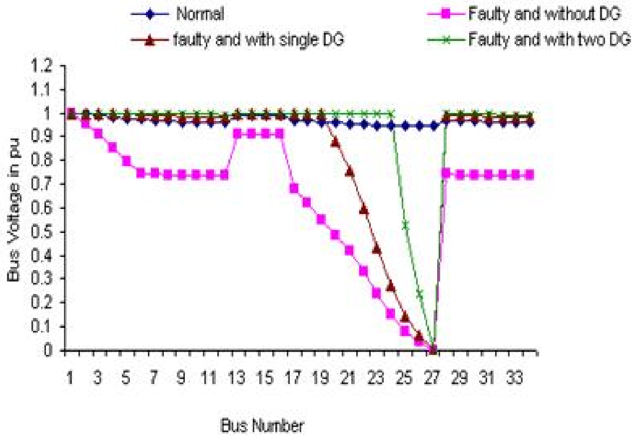


Figure.-3: Bus voltages at four different cases.

The GA was run 100 independent times, starting from a different initial population at each simulation. Different solutions were obtained at each run, as the initial population, which gives the first genetic material, is randomly generated. Furthermore, the entire algorithm is based on random processes. Nevertheless, because of the high ratio of similar results indicating bus number 24 and 7 as best locations, one can accept this result as accurate. Table-I shows that under normal condition total active power loss is 222kw and load disturbed due all possible faults is 169.462 MVA. Table-I shows how the loss and load disturbed value get reduce due to the introduction of DG's. It can also be concluded that how the number of DG affects on loss and sag performance.

In figure-3 a clear comparison is made among the voltage profile under four different cases. Case1: Under normal condition, Case-2: Under fault without any DG unit, case-3: Under fault with one DG unit, Case-4: Under fault with two DG unit.

## CONCLUSIONS

This paper presented a new formulation of the DG placement problem using genetic algorithm. As the authors' intention was to highlight on the necessity of incorporating the voltage sag as an objective of the optimization problem, the implementation was based on some simplified assumptions as consideration of three phase faults only or the fault locations being the system buses, etc. These limitations, however, can be overcome very easily. Currently the authors are working on these issues.

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