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Optimal Location and Sizing of Generator in Distributed Generation System

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Abstract: This paper presents a method for the optimal location and sizing of generator in Distributed generation in distribution systems. In this paper, our aim would be optimal distributed generation location and size for Power loss reduction in distribution network. In this paper, Genetic Algorithm (GA) is used for determine optimal location and size for placement distributed generators which referring two determined aim; the problem is defined and objective function is introduced. The proposed method is programmed and tested in a 16 bus distribution system using MATLAB software. The simulation results are given to verify the proposed analytical approaches.

Keywords: Distributed Generation (DG), Genetic algorithms (GA), Optimal location and sizing, Power loss.

I. INTRODUCTION

Earlier the distribution networks had been designed to convey electrical energy from high voltage transmission networks, whereby the majority of electrical generation plants were connected, to the customers [1]. There are a number of approaches proposed for placement and sizing of DG units. A second order algorithm with transformation of variables to optimally allocate DG resources in a meshed network. The convergence properties of the proposed algorithm have been examined with a six bus test system[2].A fuzzy-GA method to resolve dispersed generators placement for distribution systems with the objective to reduce power losses of distribution systems [3]. Analytical methods to determine the optimal location to place a DG in radial as well as networked systems to minimize the power loss of the system. The proposed method was tested on the IEEE 6-bus and 30-bus test systems[4].

GA as solving tool for the allocation of generators in distribution networks, in order to improve voltage profile and loss reduction in distribution network. Considering the sensitivity of the fitness values in GA, it is required to apply the load flow for a desirable decision making. Load flow algorithm is combined suitably with GA, till the access to admissible results is obtained. The authors have used MATPOWER package for load flow algorithm and composed it with the GA. The suggested method is programmed under MATLAB software and applied ETAP software for evaluating of results correctness[6], [15]. The Khoda Bande Loo distribution test feeder in Tehran has been solved with the proposed algorithm and, the simple GA and illuminated the improvement of voltage profile and loss reduction indexes.
Distributed generation (DG) can offer an alternative planning approach to utilities to satisfy demand growth and distribution network security, planning and management issues. As DG may provide many benefits for distribution network operators that can choose where to place it, as well as controlling its operating pattern through peak load operation, the recognition deferment benefits may influence the optimal connection of new generation within existing networks & suggested that proper sitting of DG may defer T&D expansion. Also it is accepted by many countries that the reduction in gaseous emissions (mainly CO_2) offered by DGs is major legal driver for DG implementation [5],[6].

GA based optimization technique (which can give near optimal results), suitable for multi- objective problems like DG allocation with optimal power flow (OPF) calculations has been used by Silvestri [7]. A hybrid GA-OPF approach was proposed by Harrison [8] for finding optimal location for connecting a predefined numbers of DGs in a distribution network Jabr and Pal [9] presented an ordinal optimization (OO) method for specifying the locations and capacities of distributed generation (DG) such that a trade-off between loss minimization and DG capacity maximization is achieved. Acharya in[10] suggested a heuristic method to select appropriate location and optimal value of DG capacity for minimum real power losses of the system by calculating DG size at different buses. Though the method is effective in selecting location, it requires more computational effort. The heuristic method used to calculate DG size is based on approximate loss formula and it may lead to an inappropriate solution.

In this paper provides the detailed analysis of optimal placement and sizing of DG in electrical power systems. The methods are presented to find optimal size and bus location for placing DG using power loss and energy loss minimization in a networked system based on bus admittance, generation information and load distribution of the system. The proposed methods are tested by simulations on 16-bus test system distribution system. An effectiveness of proposed methods is tested by determining the optimal size and bus for placing DG under voltage and line loading constraints with uniform loading conditions in system power loss minimization and time-varying loading conditions in system energy loss minimization conditions there are more constraints on availability of DG sources and we may only have one or a few DGs with limited output available to add. The method to determine the optimal size and bus for placing the DG

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may also need to take into account other factors, such as economic and geographic considerations. These factors are not discussed in this paper.

II. PROBLEM FORMULATION

DG sources are normally placed close to load centres and are added mostly at the distribution level. They are relatively small in size (relative to the power capacity of the system in which they are placed) and modular in structure. A common strategy for sizing and placement of DG is either to minimize system power loss or system energy loss of the power systems. The voltage at each bus is in the acceptable range and the line flows are within the limits. These limits are important so that integration of DG into the system does not increase the cost for voltage control or replacement of existing lines. The formulation to determining the optimal size and location of DG in a system is as follows:

A. Location Selection

The loss sensitivity factors at different buses have been evaluated to select appropriate nodes for DG planning by using load flow program suitable to radial networks suggested by Afsari et al. (2002). These sensitivity factors reflect how the feeder power losses change if more real power is injected at a particular node and it also allows obtaining the candidate nodes to locate DG.

Analytical approaches for optimal placement of DG with unity power factor is to minimize the power loss of the system. A "2/3 rule" is used to place DG on a radial feeder with uniformly distributed load, where it is suggested to install DG of approximately 2/3 capacity of incoming generation at approximately 2/3 of the length of line. In above approaches size of DG is not optimized. Line loading constraint is not considered during optimization. The benefit expressed as a performance index can be the minimization of active power losses, var losses, or loading in selected lines. The expression for line losses describe by Elgard [11] has been used for the purpose. The change in active power loss of the system due to change in active power injection at a node is expressed as expressed as

$$\frac{\partial P_{Loss}}{\partial P_i} = 2\sum_{j=1}^{n}\left(\alpha_{ij}P_i - \beta_{ij}Q_i\right) \tag{1}$$

$$P_{Loss} = \sum_{i=1}^{n}\sum_{j=1}^{n}\alpha_{ij}\left(P_iP_j + Q_iQ_j\right) + \beta_{ij}\left(Q_iP_j - P_iQ_j\right) \tag{2}$$

The objective function is to minimize the active power loss using Equation (10) and formulated as to minimize

$$P_{Loss} = \sum_{k=1}^{LN} Loss_k \tag{3}$$

Subject to

$$\sum_{i=1}^{n} P_{Gi} \leq \sum_{i=1}^{n} \left(P_i + P_{Loss}\right) \tag{4}$$

$$V_i^{\min} \leq V_i \leq V_i^{\max} \tag{5}$$

$$\left|I_{ij}\right| \leq \left|I_{ij}\right| \tag{6}$$

C. . Demand Curve

Day to day demand curves vary as per the demand of loads. Seasonal variations, social commotion, economic and environmental aspects also dictate the changes in demand curve. Since the final solution depends on proper choice of demand curve, a careful analysis is required. All the individual buses demand curves are considered identical to the demand curve taken at substation. This assumption is really necessary because individual demand curves for each bus are rarely available. In addition, this assumption does not interfere in the result significantly, especially when the feeder supplies many loads and the influence area is homogenous like a residential, commercial, rural or industrial area[12-15].

Table1: Duration of various load levels and other details for the considered systems.

Load Levels			
Load level	0.624	1.000	1.28
Duration	1000	6762	1000
Loss without DG	79.8825	216.0	351.508
Lowest voltage	0.9444	0.9080	0.8822

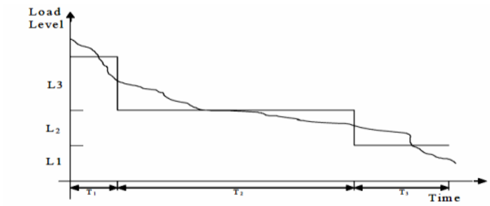

Fig. 1: Approximated Load–Duration Curve

III. GENETIC ALGORITHM

Genetic algorithms (GAs) are stochastic global search and optimization methods that mimic the metaphor of natural biological evolution. GAs operates on a population of potential solutions applying the principle of survival of the fittest to produce successively better approximations to a solution. At each generation of a GA, a new set of approximations is created by the process of selecting individuals according to their level of fitness in the problem domain and reproducing them using operators borrowed from natural genetics. This process leads to the evolution of populations of individuals that are better suited to their environment than the individuals from which they were created, just as in natural adaptation.GA has been applied in several problems and excellent texts[16-20].

The advantages in using GA are that they require no knowledge or gradient information about the response surface; they are resistant to becoming trapped in local optima and they can be employed for a wide variety of optimization problems. On other hand GA could have trouble in finding the exact global optimum and they require a large number of fitness functions evaluations. It is very difficult to achieve analytic relationship between sensitivity of simulated power system and the parameters values to be optimized. Since GA don't need this kind of information, it is suitable in our optimization task. If there is an explicit knowledge about the power system being optimized, that information can be included in the initial population. In this work we initialize the population to the best-fit results. An evolutionary strategy needs to be

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adopted in order to generate individuals for the next generation. The individuals are arranged by their fitness and only the best of them are taken unchanged into the next generation. In this way good individuals are not lost during a run. Other children come from crossover and mutation. The aim of the fitness function is to numerically represent the performance of an individual. In order to end the evolution of the population we choose certain termination criterion. The final result of the GA optimization is the best individual of the last iteration.

A. Selection of GA parameters

In the initialisation, the first thing to do is to decide the coding structure. Coding for a solution, termed a chromosome in GA literature, is usually described as a string of symbols from {0, 1}. These components of the chromosome are then labelled as genes. The number of bits that must be used to describe the parameters is problem dependent. Let each solution in the population of m such solutions xi, i=1, 2, .. ., m, be a string of symbols {0, 1} of length l. Typically, the initial population of m solutions is selected completely at random, with each bit of each solution having 50% chance of taking the value 0.

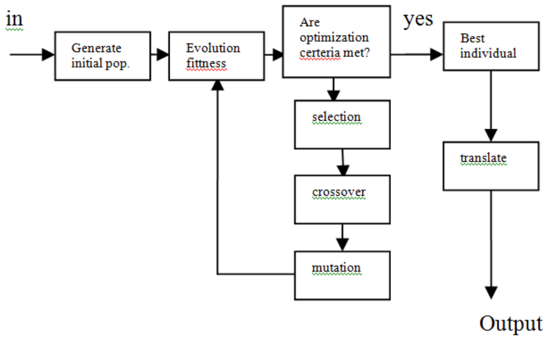

Fig. 2: Standard procedure of a canonical genetic algorithm.

Genetic algorithm that yields good results in many practical problems is composed of three operators:

- **Crossover:** the individuals, randomly organized pair wise, have their space locations combined, in such a way that each former pair of individuals gives rise to a new pair.
- **Mutation:** some individuals are randomly modified, in order to reach other points of the search space.
- **Selection:** the individuals, after mutation and crossover, are evaluated. They are chosen or not chosen for being inserted in the new population through a probalistic rule that gives a greater probability of selection to the "better" individuals

B.. GA Implementation

The GA technology is particularly suitable for the solution of combinatorial optimization problems. The advantages of using GA are that they require no knowledge of gradient information about the response surface; they are resistant to becoming trapped in local optima and can be employed for a wide variety of optimization problems. The GA methodology discussed above is implemented using following steps[24]:

Step 1: randomly generate size-location pairs of distributed generation system in a predefined range of sizes and the buses. Set k=1. Enter the maximum number of iteration m.

Step 2: run power flow and calculate power loss of the system for each size-location pair under uniform loading condition, and record the power loss and its corresponding size-location pairs.

Step 3: check whether the voltage limits and transmission line MVA limits are satisfied for all the buses for each of the size location pairs.

Step 4: if all the voltages and MVA limits are in acceptable range for a particular size-location pair, accept that pair for next generation population. Else reject the size-location pair which does not satisfy criteria given in step 3 in the next generation. Obtain the size-location pair with minimum power loss (min_ploss_size_location (k)). If k=m, the size and location corresponding to this is the optimum-size location pair. STOP and END the program.

Step 5: use the available population of size-location pair (parent population) for cross-over and mutation for obtaining new generation of (offspring) population. If population size does not satisfy criteria system loadings respectively. Distributed generation (DG) sizes obtained for system. Power loss corresponding to bus locations is presented in.

Step 6: use the newly generated population size i.e. off springs and parents as new generation. Go to step 2.

IV. RESULTS & DISCUSSION

In order to see the best location of DG in the distribution system with the view of minimizing the total real power losses, genetic algorithm is used. Several simulation studies have been carried out to obtain the best size and location of a DG for 16-bus test systems. The data used as shown in appendix-1A [24].

A smaller 16-bus system as shown in Fig. 3. The 16 bus which can be considered as a sub transmission/distribution system, are used to verify the method presented above. optimal location and size of generator in distributed generation system by using GA based power loss minimization approach is implemented to place single DG in any distribution systems.

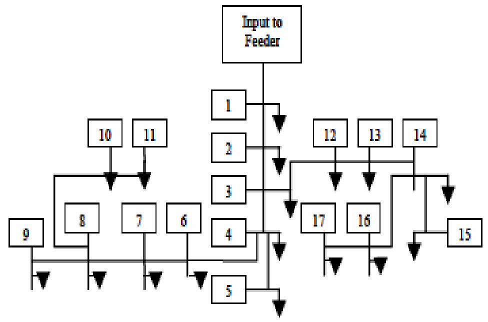

Fig. 3. 16-bus test system

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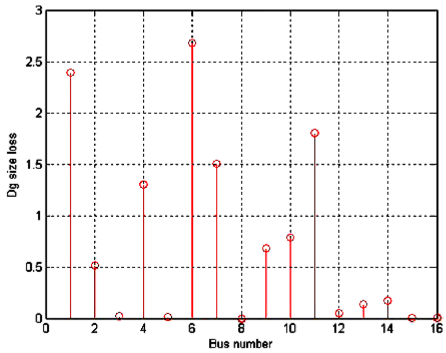

Fig. 4. Losses between bus number and DG size

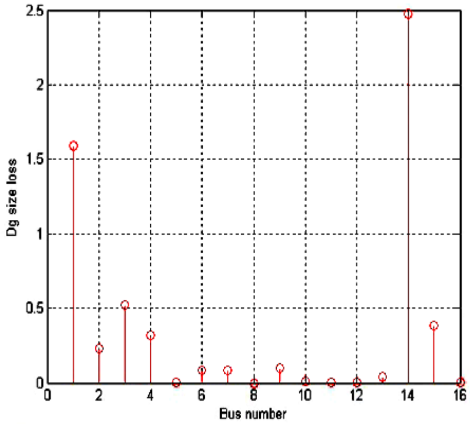

Fig. 5. Optimal location for DG in different buses

In the above fig.4 it is observed that at bus 6 the DG size loss is maximum and in 1, 4, 7, 5, 10, & 11 losses is high. To reduce these losses by using of evolutionary technique using Genetic Algorithm (GA).With the help of GA it minimize the power losses and we get optimal location for Generator. It is observed that in Fig.5 the DG power loss in 1, 4, 7, 5, 10 & 11 become minimum. By using GA losses are optimized and we get optimal location for Generator. In bus 5,8,11 there is very minimum losses occur which is best suitable for DG location.

A. 16-bus system

A 0 - 0.63 p.u. range DG was selected to be placed in the 16-bus test system shown in Fig. 6 Total system power loss is obtained from the results of power flow studies when DG in said range is placed at all the 16 buses for peak, medium and low system load.

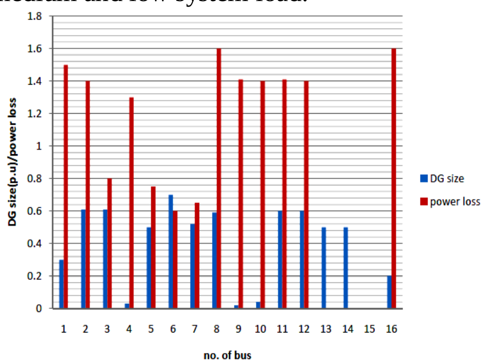

Fig. 6 DG size, Bus location & System power loss of 16-bus test system with peak load.

From the above studies the size for the DG for a particular set of buses which satisfies all the voltage and line flow limits are depicted in Figs. 6, 7, and 8 for peak, medium and low system loadings respectively. DG sizes obtained for system power loss corresponding to bus locations is presented in these bar charts.

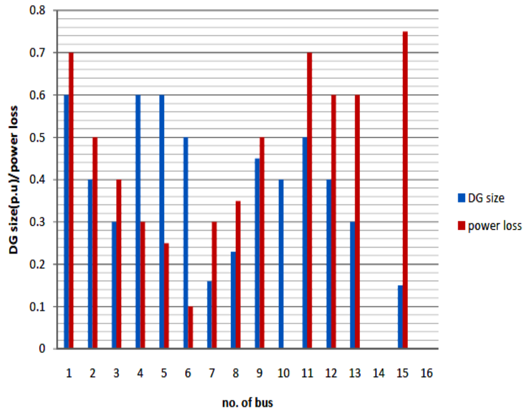

Fig. 7. DG size, Bus location & System power loss of 16-bus test system with medium load.

It is observed from Fig. 6 that buses 2-8, 10-14 & 17 are locations at which a DG of 0-0.60 p.u. can be added without violating the system's voltage and line flow limits. It is also observed that bus-7 with DG size of 0.52 p.u. is suitable for minimum power loss. From Fig. 7, it is seen that, in case of medium loading condition, buses 2-4, 5-8, 9-11 & 12 are sensitive. From Fig. 8 it is seen that, in case of low loading condition, sensitive buses are 2-3, 6-7, & 12. The minimum system loss is obtained by placing a DG at bus 6 of 0.3 p.u. and 0.23 p.u. respectively for medium and low loading conditions.

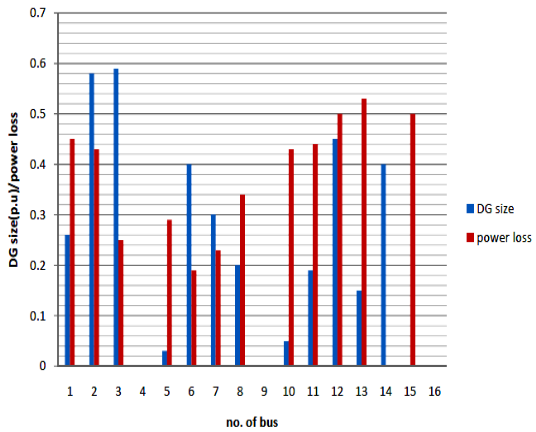

Fig . 8. DG size, Bus location & System power loss of 16-bus test system with low loading condition

It is to be noted that though the maximum allowable DG size was 0.6 p.u. but the DG sizes which can be employed without violating voltage or line limits is 0.60 p.u., 0.30 p.u., and 0.23 p.u. for at bus-6 for peak, medium and low system loading conditions respectively. The size and location obtained using the proposed GA method for minimum system power loss for three loading conditions. It is observed that the solutions which were obtained through detailed analysis were same as that obtained by proposed method.

V. CONCLUSION

This paper discusses simulation approach for the optimal location and sizing of a DG .Minimization of power loss in 16-bus, distribution systems is performed under peak medium and low loading condition. It is pointed out that losses vary as a function of loading. Often, DGs are placed at substations for convenience. However, placing a DG further out on the system as opposed to locating the DG at the substation can reduce power losses. Often in industry, decisions are based on power flow analysis run for the peak load. Placing a DG where peak load condition is evaluated may not provide the best location for minimum loss. The optimal DG placements for minimum loss are different during light load conditions and close to one another during heavy load periods.

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Appendix

Table. 2. Load data for 16 bus taken form [24].

		Line Impedance in p.u.				Loads on to-node (p.u)		
F	T	R p.u.	X p.u.	L	S_L	P	Q	L_T
1	2	0.000574	0.000293	1	4.6	0.1	0.06	R
2	3	0.00307	0.001564	6	4.1	0.09	0.04	I
3	4	0.002279	0.001161	11	2.9	0.12	0.08	C
4	5	0.002373	0.001209	12	2.9	0.06	0.03	R
5	6	0.0051	0.004402	13	2.9	0.06	0.02	I
6	7	0.001166	0.003853	22	1.5	0.2	0.1	C
7	8	0.00443	0.001464	23	1.05	0.2	0.1	C
8	9	0.006413	0.004608	25	1.05	0.06	0.02	I
9	10	0.006501	0.004608	27	1.05	0.06	0.02	C
10	11	0.001224	0.000405	28	1.05	0.045	0.03	C
11	12	0.002331	0.000771	29	1.05	0.06	0.035	R
12	13	0.009141	0.007192	31	0.5	0.06	0.035	C
13	14	0.003372	0.004439	32	0.45	0.12	0.08	R
14	15	0.00368	0.003275	33	0.3	0.06	0.01	C
15	16	0.004647	0.003394	34	0.25	0.06	0.02	I
16	17	0.008026	0.010716	35	0.25	0.06	0.02	C

F=From node, T=To node, L=Line number, S_L =Line MVA limit in p.u., P= Real MW load in p.u. ,Q= Reactive MVAr load in p.u., L_T =Load Type, R=Residential, I=Industrial, C=Commercial

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