Optimal Location And Sizing Of Distributed Generators In Distribution System.

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Abstract— **This paper presents an approach for Distribution expansion planning by taking distributed generators into account. In order to supply electric power to consumers in a reliable and economic manner, distributed generators is considered to be one of the best solution. Distributed generators are also called on-site generators or dispersed generators. It generates electricity from small energy sources. DG has the advantages of power loss reduction, voltage improvement, increasing reliability, environmental friendliness. In order to reduce the cost and power loss of the system, DG unit size and location should be optimal. In this paper genetic algorithm is used as the optimization technique for finding optimal size and location of DG for reducing the power loss. To reveal the validity of GA standard IEEE 5 Bus system, 16 Bus system, and 30 Bus systems are examined.**

Keywords— *Distribution planning, Distributed generators, Genetic algorithm, power loss reduction*

I. INTRODUCTION

The electric utility system is usually divided into three subsystems which are generation, transmission and distribution [1]. In this distribution plays a very important part as the consumers are directly affected by its efficiency. So proper planning will increase the efficiency and overall performance of the distribution system. The load demand is increasing day by day, in order to satisfy the customer's need, expansion of the existing power system is essential. Expansion means transformer up gradation, substation up gradation, feeder reconfiguration etc. are the methods. These methods are complex and not economical. To overcome all these problems distributed generators are used for distribution expansion planning.

The considerable advantages of Distributed generation (DG)-unit system are power loss reduction, environmental friendliness, voltage improvement, postponement of system upgrading and increasing reliability [2]. The planning of the power electric system with the presence of DG requires the definition of several factors such as: the best technology to be used, the number and the capacity of units, the best location, the type of DG unit and network connection, etc. the problem of allocation and sizing is of great importance[3]. The implementation of DG on non optimal places can results in an increase in system losses, cost and therefore having an effect opposite to the desired.

The figure1 shows the power loss versus size of DG in standard 30 bus system. It is not advisable to construct sufficiently high Dg in network. As the size of DG is increased the losses at a particular bus starts to decrease but the size is increased beyond a limit the losses starts to increase. So as mentioned earlier the optimal size and location of DG place an important role in distribution networks.

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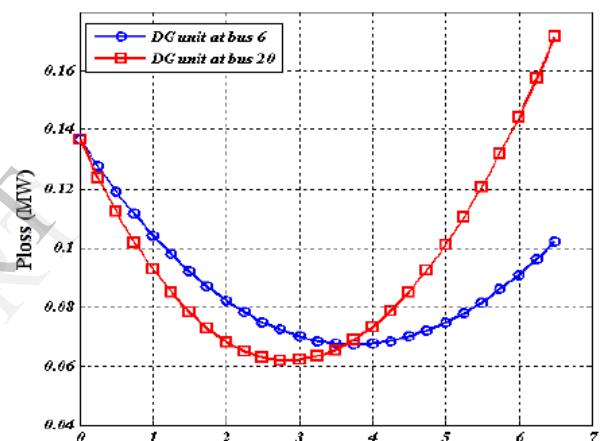
The optimal placement of the DG units has been continuously studied in order to achieve different aims [4]. The objective can be the minimization of the active losses of the distribution network, or the minimization of the total network supply costs, which includes generators operation and losses compensation. In this paper GA algorithm is used as the optimization technique to allocate DG units optimally in order reduce power loss of distribution network.

The organization of this paper is as follows; in section II, a brief discussion of distributed generation issues is presented. Section III addresses the problem formulation. Section IV is an introduction to the Genetic algorithm. The proposed solution method is discussed in section V. In section VI, two test systems used for simulations, is introduced. Simulation results on the test systems are illustrated in section VII. Then, the conclusion is given in section VIII.

II.   DISTRIBUTED GENERATORS

The term Distributed Generation is used to describe small size power-generating units (rated capacities of up to 100 MW) which are located closer to energy consumers in the distribution grid. There are significant amounts of newly emerged generation technologies with promising values for efficiencies and emissions. Some of these technologies are still under improvement while others are being sold in the market. Distributed generation (DG) contributes only a small amount to our nation's electricity supply. As of 2005, approximately 12.3 million DG units were installed in the United States. Collectively these units represented approximately 234 GW of capacity, however less than 1 percent of them were connected to the grid. The majority of these units are small reciprocating engines used to supply emergency or standby power.

III.   PROBLEM FORMULATION

A multi-objective optimisation technique, formulated as a constrained GA optimisation problem, is proposed for DG placement and sizing in a distribution system. The objective is to minimise the total power loss.
. The fitness function is given by Eq. (1):

$$F_{min}=P_{loss} \qquad (1)$$

where F is the fitness function, $Ploss$ is the total power loss.
The total real power loss is defined by

$$P_{loss}=\sum_{i=n}^{n} P_{loss}, \qquad (2) \text{ where } i= 1,2,….n$$

Where n is the number of lines.
The inequality constraints involve those associated with the bus voltages and the DG to be installed. The bus voltage magnitudes are to be kept within acceptable operating limits throughout the optimisation process, as follows:

$$V min<VI<Vmax$$

where Vmin is the lower bound of bus voltage limits, Vmax is the upper bound of the voltage limits, and $| Vi |$ is the root mean square (RMS) value of the ith bus voltage.
The active power loss in the kth line is indicated by Eq. (2):

$$P_{loss}= I_k^2*R(K) \qquad ………….. \qquad (3)$$

Where Ik is the branch current and R is the resistance of the line. In addition,

$$I_k = [P[j]+Q[j]/V[j]]* ………. \qquad (4)$$
$$= P[j]+Q[j]/V[j]* ……… \qquad (5)$$
$$P_{loss}= (P^2[j]+Q^2 [j])*R[K]/(V[j])^2 ……. \qquad (6)$$

Thus, the buses will be ranked based on Eq. (6) accordingly. Some buses will be nominated as the most sensitive to DG placement in order to have the best effect on loss reduction.

IV.   GENETIC ALGORITHM

GA derives from the principles of genetics and evolution. Genetic algorithms are heuristic algorithms based on the mechanism of natural selection [6]. It allows a population composed of many individuals to evolve under specified selection rules to a state that maximizes the fitness [8]. It introduces the principle of evolution and genetics to search for possible solution to a given problem. The main principle of evolution used in GA is "survival of the fittest" meaning the best solution survives while the bad ones are discarded. Unlike the other methods GA has the ability to handle any type of objective functions, variables and constraints. GA, one of the evolutionary methods is very comprehensive. The method offers not one ideal solution but a set of applicable near optimal solutions at reasonable amount of computation time [9].

The advantages of GA can be summarized as:
1. Optimizes with continuous or discrete variable.
2. Simultaneously searches from a wide sampling of the cost surface.
3. Deals with a large number of variables.
4. Provides a list of optimum variables, not just a single solution.
5. Optimizes variables with extremely complex cost surfaces.
6. May encode the variables so that the optimization is done with the encoded variables and
7. Works with numerically generated data, experimental data, or analytical functions.

A. GA Solution Procedure

The genetic algorithm is a method for solving both constrained and unconstrained optimization problems[5] that is based on natural selection, the process that drives biological evolution. The genetic algorithm repeatedly modifies a population of individual solutions. Some of the commonly used terminologies in GA are *fitness function*- which we want to minimize and *population*- an array of individuals. The algorithm starts by creating random initial population. If the initial population is specified, it creates a sequence of new population. To create new population it scores each member of the current population by computing the fitness value. It then elects members, called parents, based on their fitness [9].
The individuals in the current population that have lower fitness are chosen as elite. These elite individuals are passed to the next population to form children. Children are produced either by making random changes to a single parent like mutation or by combining pair of parents i.e. crossover. The algorithm then checks for the constraint violation. The algorithm stops when the fitness value converges or until a pre-specified number of generations have been reached. A generalized procedure for GA is summarized below.
1. The first step is to define the objective function and variables.
2. In the second step the GA parameters are selected and the population is initialized.

3. After initialization the elite and parents are selected based on the fitness value.

4. Once the parents are selected either mutation or crossover is performed form offspring.

5. The offspring is then inserted into the new population.

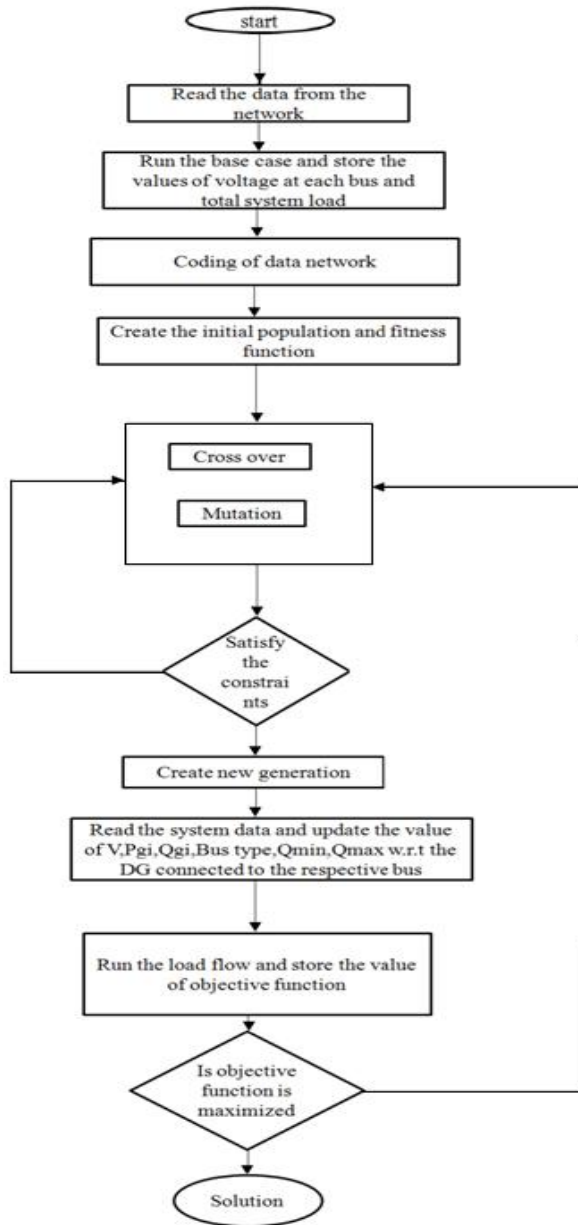6. The last step is to check if the optimum solution has been achieved.

Fig. 2 Flow chart for genetic algorithm

V.   PROPOSED METHODOLOGY

The following steps are used by the GA technique to solve the distribution expansion planning problem.

Step 1: Randomly choose a set of pairs (location, capacity) of distributed production.

Set k =1. Enter the maximum number of iterations m.

Step 2: Calculate the losses in the system based on the power flow of each pair (location, capacity) by modelling the distributed production by using negative load. Record the losses related to each pair. (Location, capacity).

Step 3: Check if all the conditions are met for each pair (location, capacity) in terms of voltage and line load for each bus and each line.

Step 4: If all the voltages and loads in MW are within limits for the matching pair (location, capacity) accept the pair for the population of the future generation. Otherwise, reject the pair that does not meet the criteria (location, capacity) and do not use it for the future population.

Find a pair (location, capacity) which has minimum losses. If $k = m$ is presented as a pair (location, capacity) to minimum losses. The end.

Step 5: Use a surviving population of pairs (location, capacity) and submit them to a crossover and mutation to get a new generation. If the population, after Step 4, equals zero return to Step 1

Step 6: Use a new, randomly chosen population as offspring. Move to Step 2.

The best position includes the optimal locations and size of DG units and the corresponding fitness value representing the minimum total real power loss.

VI   CASE STUDY

In this paper simulations are carried out on 5-bus, 16-bus, and 30-bus test distribution systems. Case 1 considers IEEE 5bus system, case 2 considers IEEE 16 bus systems and case 3 considers IEEE 30 bus system. Schematic diagram of the 5, 16, and 30 bus test system used in this paper are shown in Fig. 3.
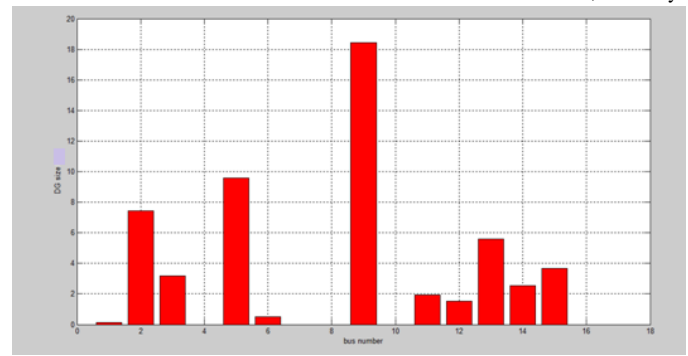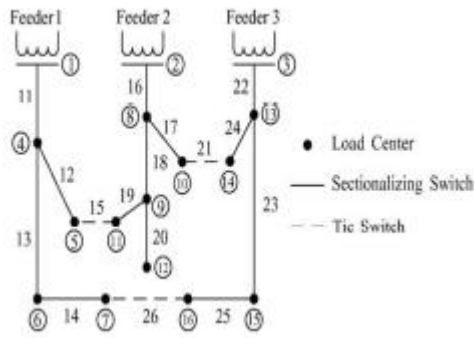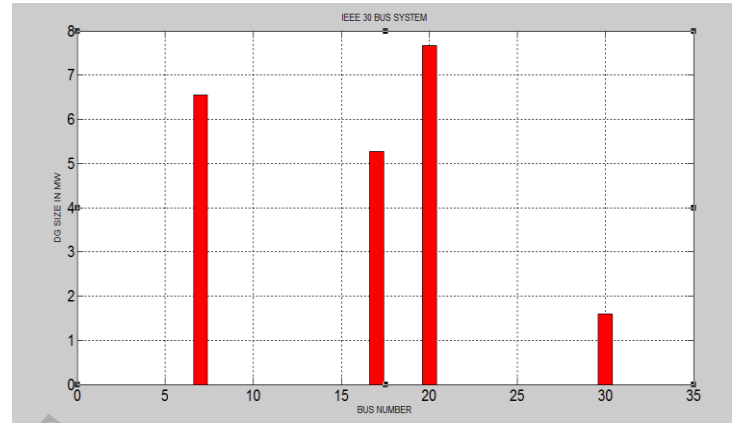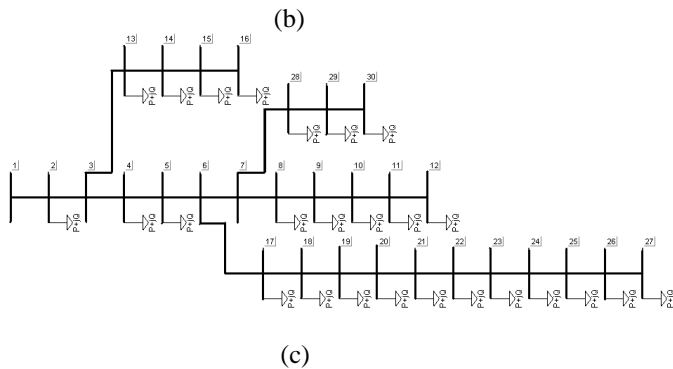

(a)

Fig.5

(b)

(c)
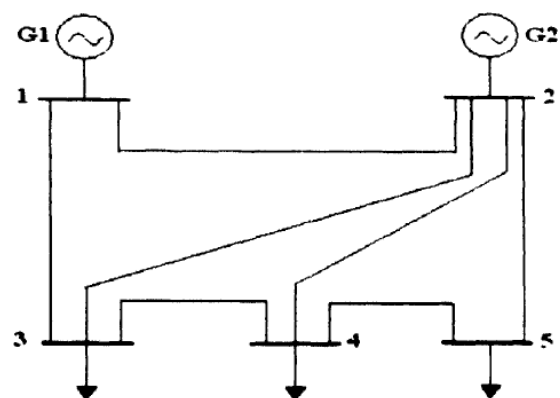
Fig 3 (a) 5-Bus (b)16-bus and (c) 30-bus test systems

VII   SIMULATION RESULTS

As mentioned before simulation is performed on the 5, 16 and 30 buses test systems in order to calculate the Ploss in absence of DG units in the system. The obtained results are shown in the table. The results obtained by GA for the optimal location and sizing of DG are shown in Fig. 4, 5 and 6.
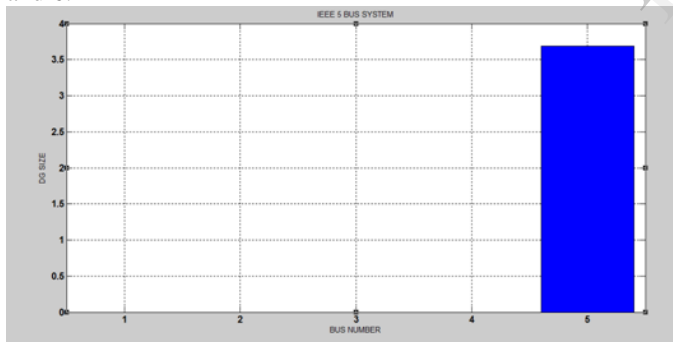

Fig. 6

Power loss with and without DG for 30 bus system

Optimum location	Optimum DG size	Powe loss(KW)	
		Without DG	With DG
Bus 7	6.7	210.97	111.2
Bus 17	5.3	210.97	123.72
Bus 20	7.8	210.97	111.02
Bus30	1.7	210.97	130.12

Fig.4

.   VIII   CONCLUSION

The optimal placement and sizing of distributed generators for minimizing the losses by applying a genetic algorithm is tested on 5,16and 30 bus systems. It shows a fast convergence towards a set of optimal solution. The optimal placement of DG by GA taking the limits of the system in consideration to minimize the real power losses. But in practice the best location or size may not always be practical due to many reasons, i.e. such size may not be available in the market.

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