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# Optimal Placement of Distributed Generation Resources

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***Abstract -*** Recent developments in the electric power and problems arising from construction and maintenance of large power plants have raised a great deal of interest in distributed power generation (DG). Distributed generation units due to specifications, technology and location network connectivity can improve system and load point reliability indices. In this paper, the placement and sizing of Distributed Generators (DG) in distribution networks are determined using optimization. The objective is to improve the reliability indices. The placement and size of DGs are optimized using a Genetic Algorithm (GA). To evaluate the proposed algorithm, the IEEE 34 buses distribution feeder,is used. The results illustrate the efficiency of the proposed method.*)*

***Keywords****-component; Distributed Generation, Distribution System, Optimization, Reliability*

## I. INTRODUCTION

Due to competition and restructuring in power systems and changes in management and ownership of electricity industry, the role of distributed generation units expected to be increasingly in the future. Also, factors such as environmental pollution, problems establishment of new transmission lines and technology development of DG unit increase the use of these resources. Although, use of DGs can lead the distribution network to lower loss, higher reliability, etc, it can also apply a high capital cost to the system. This demonstrates the importance of finding the optimal size and placement of DGs. In recent years, several studies have considered techniques for locating DG units on distribution systems. In all papers, improvement of system characteristics is the main objective of DG placement. Almost all papers related to DGs have studied loss minimization and improve voltage profile [2-9] and a few papers have examined DGs for improving the reliability [1, 10].

This paper is organized as follows. Effect of DG on system reliability and reliability assessment introduced in section II .In Section III, the problem is formulated, where the optimum placement DGs in distribution networks is introduced and a composite reliability index is defined. In Section IV, the proposed method for optimal DG placement by genetic algorithm is detailed. Simulation results and conclusions are expressed in Sections V and VI.

## II. DISTRIBUTION SYSTEM RELIABILITY ASSESSMENT

Reliability evaluation of distribution systems has received considerable attention and there are a number of publications dealing with modeling and evaluation techniques. However a continuing need to extend and develop the techniques still remains as new design and operation approaches are introduced into the system [1]. There are several available methods for evaluating the reliability of distribution systems.

In this paper, the impact to all load points due to each component failure will be considered as well as the average failure rate of the component. Then, the interruption frequency and duration at each load point is calculated to eventually calculate the system reliability indices. The important point is that it should be noted that in each errors simulation, the effect of the network structure, switches, supply ability of loads from the main source of power or other resources, islanding of DGs in the simulation must be modeled properly. Note the simple illustrative distribution system as shown in Figure 1 for further explanation. The feeder is operated as radial feeders but it can be supported by a DG through a normally open switch. For example following a fault occurrence on first section, with no DG on the feeder, service of all load points must be interrupted during repair process but with DG as shown in Fig 1, some load points loads (due to DG capacity) can be restored via the DG. Existence of DGs can reduce the outage duration and consequently increase the system reliability.

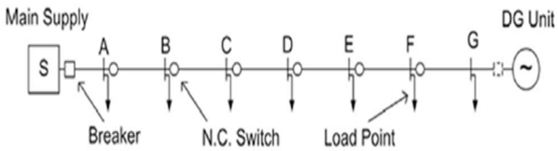


Fig. 1 : A Typical distribution system with one DG

This simple example shows that DG can have a positive impact on distribution system reliability in the case of local utility supply interruptions. Distribution automation system in a distribution system including DGs, load transfer to other feeders via switches operation can be performed in fault condition in order to keep customer supply. [11,13]

## III. PROBLEM FORMULATION

The objective of DGs placement in a radial feeder is to maximize the distribution network reliability under certain constraints. As a brief reminder, we will look at the standard reliability performance indices, such as system average interruption duration index (SAIDI) , system average interruption frequency index (SAIFI) and energy not supply index (AENS) and the composite index obtained as a combination of all three. They are defined as follows:

(1) $$SAIFI = \frac{\sum \lambda_i . N_i}{\sum N_i}$$

where $N_i$ is the number of customers of load point i and $\lambda_i$ is the failure rate.

(2) $$SAIDI = \frac{\sum u_i N_i}{\sum N_i}$$

where $u_i$ is the outage time.

(3) $$AENS = \frac{\sum L_{a(i)} u_i}{\sum N_i}$$

Where $L_{a(i)}$ is the average load connected to load point i.

For the purpose of optimization, we define a composite reliability indices and capacity of DG units through weighted aggregation of these indexes.

(4) $$OBF = w_{SAIFI} \cdot \frac{SAIFI}{SAIFI_T} + w_{SAIDI} \cdot \frac{SAIDI}{SAIDI_T} + w_{AENS} \cdot \frac{AENS}{AENS_T} + w_{PDG} \cdot \frac{PDG}{PDG_T}$$

Where $w_x \geq 0$ are the weighting coefficients representing the relative importance of the objectives and the subscript T indicates the target value. These reliability indices are the most widely used indexes for measuring the distribution system reliability. In this formulation, we incorporate the desired values these reliability indices that are empirically justified.[10]

## IV. IMPLEMENTATION OF GA

Due to the discrete nature of allocation and sizing problem, it undergoes a number of local minima. To deal appropriately with this issue, using a reliable optimization method is required. The optimization methods are mainly divided into analytical and heuristic methods. The analytical methods show higher accuracy compared with the heuristic methods in the smooth functions. However, the objective function in the discrete problems is non-smooth which reduce the accuracy of the analytical method and lead them occasionally to be stuck in the local minima. For optimizing this type of functions, the heuristic algorithms play an acceptable role. They are based on the random values and if only one of these random values is located close to the global minimum, they can find acceptable solution [12]. In this paper Genetic Algorithm (GA) is used to achieve optimal response. GA simulates the biological processes that allows the consecutive generations in a population to adapt to their environment. Genetic Algorithm is unconstrained optimization methods, which model the evolutionary adaptation in nature. They work with a population of solutions and create new generations of solutions by appropriate genetic operators. The description and comments of algorithm implementation are presented as follows.

**Step1: convert the problem variables to Codes used for GA operators**

In this method any bus is encoded by three bits. The first bit indicates the presence or absence of DG units and next two bits represent the capacity of the unit is installed in bus. So length of each chromosome is equal to: 3 multiplied by number of buses. Capacity of distributed generation units 0.3, 0.6, 0.9, 1.2 MW is intended.

**Step2: The initial population**

To each of the chromosome genes are randomly assigned to zero or one. The initial population consists of 20 members.

**Step3: Calculation of reliability indices and the objective function**

In this step Constraints are examined and if the answer is not satisfactory, a large number as a penalty factor is added to the objective function.

**Step4: The GA operators (Roulette Wheel Selection, Cross Over, Mutation)**

To avoid trapped in local minimum during the program, amount of mutation probability is changed and amount of cross over probability has been selected 0.2.

**Step5: Check convergence criterion**

If Iter=Itermax or if the output does not change for a specific number of iterations, the program is terminated and the results are printed, else the programs goes to step 3.

## V. RESULT

To validate the proposed method, the IEEE 34 buses distribution feeder, as shown in Figure 2, is studied. The reliability index weights are chosen as follows:

$W_{SAIFI} = 0.31$, $W_{SAIDI} = 0.31$, $W_{AENS} = 0.31$ and $W_{PDG} = 0.07$. The target values of the reliability indices are set as follows: $SAIFI_T = 10$, $SAIDI_T = 100$, $AENS_T = 350$ and $PDG_T = 1000$. They are empirically justified and indicate the satisfactory level of reliability [10].The lines and loads specification of the test system are given in Table II, III.[13,14]

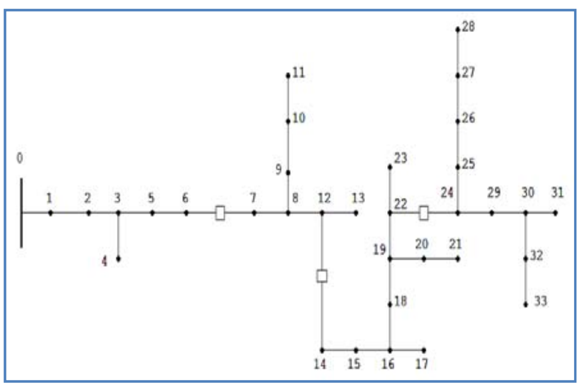


Fig. 2 : Test system

Fourth place after the implementation of algorithms for distributed generation units is proposed (The bus 11 and 18 and 19 and 25, respectively, with capacities of 600, 300,300, 900 kW) that network will reach the best reliability. As observed in Table I, after interconnection of DGs, the system reliability indices decrease.

TABLE I. COMPARISON OF OUTPUTS BEFORE AND AFTER INSTALLATION OF DGS

| | SAIFI | SAIDI | AENS | OBF |
|---|---|---|---|---|
| Without DGs | 8.7 | 92.4 | 461.4 | **0.58** |
| With DGs | 1.2 | 5.2 | 25.9 | **0.22** |

For a better understanding of how change in reliability indices, Indices changes in figure (3-5) are shown.

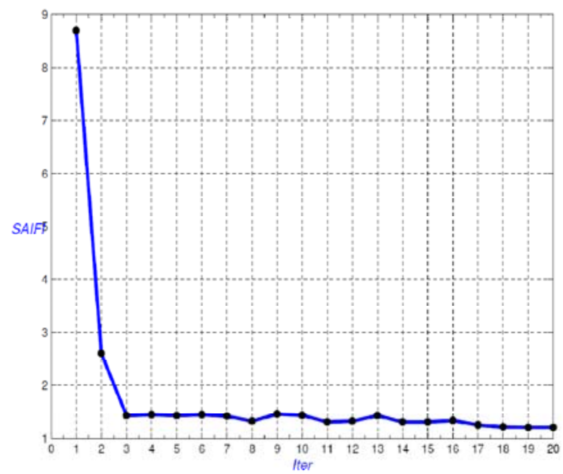


Fig. 3 : Variation of SAIFI Index

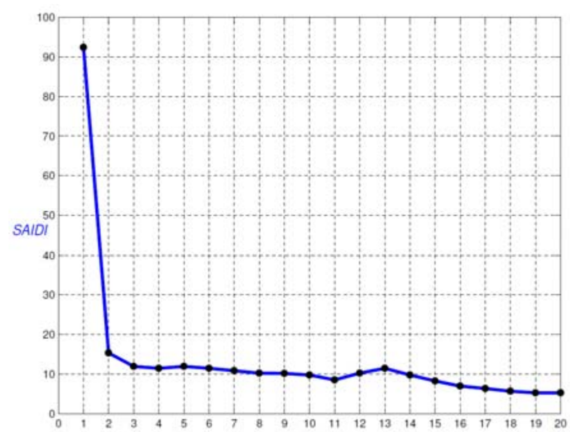


Fig.4: Variation of SAIDI Index

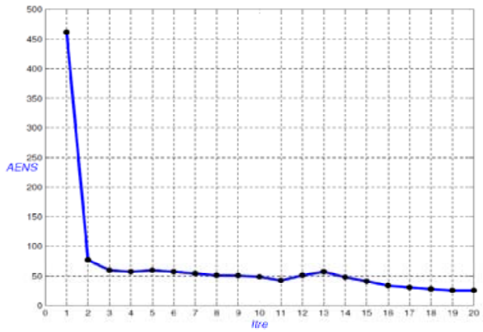


Fig. 5 : Variation of AENS Index

## VI. CONCLUSION

This paper presents a problem formulation and solution for the placement and sizing of DGs optimally. To evaluate the proposed algorithm, the IEEE 34 buses distribution feeder, is used. The results are finally compared with the no DG condition and it show that reliability indices especially Energy Not Supply index (ENS) has improved considerably with optimal placement of distributed generation and beneficiary companies acquire more benefits.

Table II : Loads specification of the test system

| P KW | Q KVAR | No . Customers | BUS No. | P KW | Q KVAR | No . Customers | BUS No. |
|---|---|---|---|---|---|---|---|
| 4 | 2 | 1 | 18 | 0 | 0 | 0 | 1 |
| 0 | 0 | 0 | 19 | 0 | 0 | 0 | 2 |
| 0 | 0 | 0 | 20 | 55 | 29 | 11 | 3 |
| 0 | 0 | 0 | 21 | 0 | 0 | 0 | 4 |
| 450 | 225 | 90 | 22 | 16 | 8 | 3 | 5 |
| 15 | 7 | 3 | 23 | 0 | 0 | 0 | 6 |
| 2 | 1 | 1 | 24 | 0 | 0 | 0 | 7 |
| 23 | 7 | 6 | 25 | 0 | 0 | 0 | 8 |
| 0 | 0 | 0 | 26 | 0 | 0 | 0 | 9 |
| 414 | 20 | 83 | 27 | 0 | 0 | 0 | 10 |
| 45 | 23 | 9 | 28 | 34 | 17 | 7 | 11 |
| 83 | 393 | 17 | 29 | 135 | 70 | 27 | 12 |
| 206 | 121 | 41 | 30 | 5 | 2 | 1 | 13 |
| 82 | 43 | 16 | 31 | 40 | 20 | 8 | 14 |
| 67 | 41 | 13 | 32 | 4 | 2 | 1 | 15 |
| 0 | 0 | 0 | 33 | 52 | 23 | 10 | 16 |
| 28 | 14 | 6 | 34 | 0 | 0 | 0 | 17 |

TABLE – III : LINES SPECIFICATION OF THE TEST SYSTEM

| λ(f/yr) | To Bus | From | Line No. | λ(f/yr) | To Bus | From Bus | Line No. |
|---|---|---|---|---|---|---|---|
| 14.04 | 18 | 16 | 18 | 0.983 | 1 | 34 | 1 |
| 0.04 | 19 | 18 | 19 | 0.65 | 2 | 1 | 2 |
| 1.98 | 20 | 19 | 20 | 12.28 | 3 | 2 | 3 |
| 4.024 | 21 | 20 | 21 | 2.212 | 4 | 3 | 4 |
| 1.867 | 22 | 19 | 22 | 14.29 | 5 | 3 | 5 |
| 0.617 | 23 | 22 | 23 | 11.33 | 6 | 5 | 6 |
| 2.221 | 24 | 22 | 24 | 0.04 | 7 | 6 | 7 |
| 0.107 | 25 | 24 | 25 | 0.118 | 8 | 7 | 8 |
| 0.512 | 26 | 25 | 26 | 0.651 | 9 | 8 | 9 |
| 1.387 | 27 | 26 | 27 | 18.35 | 10 | 9 | 10 |
| 0.202 | 28 | 27 | 28 | 5.236 | 11 | 10 | 11 |
| 0.77 | 29 | 24 | 29 | 3.891 | 12 | 8 | 12 |
| 1.021 | 30 | 29 | 30 | 1.154 | 13 | 12 | 13 |
| 0.328 | 31 | 30 | 31 | 0.32 | 14 | 12 | 14 |
| 0.106 | 32 | 30 | 32 | 7.789 | 15 | 14 | 15 |
| 1.85 | 33 | 32 | 33 | 0.198 | 16 | 15 | 16 |
| | | | | 8.891 | 17 | 16 | 17 |

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