# Application of Genetic Algorithm in the Optimum Placement of Distributed Generator in Distributed Power System

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## ABSTRACT
Genetic Algorithm is one the important stream of science and consider as hottest research area now a day's, this area has very vast application in real world. Efficient methods and technologies are highly required to this world to reduce the calculations and perform the operation in precise manner. The power system is very abstruse subject so there is a need of optimum solutions with which the system becomes optimized and economical by solving complex problem. There are many benefits to install a DG in system but the problem is there is need to do complex calculation to know the size and the placement of DG. The optimal size and location of DG for a distributed system is the basic purpose of this paper.

## Keywords

| | |
|---|---|
| BI | Benefit Index |
| D | Distribution Line Length |
| DG | Distributed Generation |
| $LL_{W/DG}$ | Line Losses with DG |
| $LL_{WO/DG}$ | Line Losses without DG |
| LLRI | Line Loss Reduction Index |
| $P_{gi}$ | Active Power of Generator at $i^{th}$ Bus |
| $P_{li}$ | Active Load at $i^{th}$ Bus |
| $Q_{gi}$ | Reactive Power of Generator at $i^{th}$ Bus |
| $Q_{li}$ | Reactive Load at $i^{th}$ Bus |
| R | Resistance |
| V | Voltage |
| VPII | Voltage Profile Improvement Index |
| X | Line Reactance |

## 1. INTRODUCTION
There is significant accretion of distributed generation resources which is encouraged through development in power generation technologies and new environment regulation. In most of the hospitals and office buildings had stand-by diesel generators as an emergency power source for use only during outages that's why the distributed generation system has been used as a standby power source for critical business. However, the diesel generators were beneficent. On the other hand, distributed generation systems such as fuel cells, micro turbines, biomass, wind turbines, hydro turbines or photovoltaic arrays are environment friendly can be a play the role of solution to meet the increasing demand of electric power and environmental regulations due to green-house gas emission [1],[2],[3]. Now a day's the 500 kW level distributed DG system is highly used, due to technology improvements in small generators, power electronics, and energy storage devices. Efficient clean fossil-fuels technologies such as micro-turbines, fuel cells, and environmental-friendly renewable energy technologies such as biomass, solar/photovoltaic arrays, small wind turbines and hydro turbines, are growingly used for new distributed generation systems. These DGS are applied to a standalone, a grid-interconnected, a standby, peak shavings, a cogeneration, etc. and have a lot of benefits such as environmental-friendly and modular electric generation, increased reliability/stability, high power quality, load management, fuel flexibility, uninterruptible service, cost savings, on-site generation, expandability, etc.

## 2. BENEFITS OF IMPLEMETATION OF DG IN DISTRIBUTED SYSTEM
The categories explained below describes the benefits of the sub-transmission and distributed system by integrating DGs into power systems [4],[5]:

### 2.1 Economical Benefits of DGs
There are various economical benefits by DG utilization can be summarized as follows:

1. Installation of DG units near the load centers defers the necessity for new expansive feeders to distribute power at consumer end, evade the construction of new substation:
2. Integration of DGs improves the system efficiency by improving the system voltage profile and reduces the feeder's power losses and also decreasing the loadings on existing electric equipments.
3. The capital cost of DG is low and also it returns back the benefit with in short period of time.
4. Installation time for DG is very low.
5. Implementing DGs for distribution system planning minimizes the investment risk due to reduced capital cost and less installation time.

### 2.2 Operational Benefits of DGs
The operational benefits of DG employment are as follows:

1. The production of safe, clean, reliable and efficient electrical energy is possible through DGs. Along with that cost of electrical energy is very low, with no or low emissions.

2. DGs directly provide power in the vicinity of the loads and help in reducing the loadings on feeders.
3. When DGs introduce in the distribution system it reduces the cost of distribution system because there is reduction in the number of electric elements such as transformers, feeders, capacitors etc.
4. DGs with their modern power electronic interface devices can be interconnected to the grid to achieve special power quality, reliability, and voltage profile requirements,
5. Customer-owned DGs can help customers by providing some portion of their demands during their peak load periods and by feeding the excess power to the grid during their light load periods. This way, they can get some revenue back from the electric utility.

# 3. METHODOLOGY

The broad technical benefits of introducing DG in any system are:-
i) Improvement of definite parameters like voltage profile, reliability and power quality.
ii) Reduction in line losses.

# 4. EVALUATION OF BENEFITS

The set of indices explained the technical benefits in terms of voltage and system losses. The voltage profile improvement index (VPII), line loss reduction index (LLRI) and over all benefit index (BI) [6], [7] are explained below:

## 4.1 Voltage profile improvement index (VPII)

The ratio of the sum of all the voltage at all the buses when DG is connected to the system to the sum of all the voltage at every bus when system is running without DG is defined as VPII. The weighing factor can also be introduced if we decide the weight of the buses for a system as from eqn (1).

$$VPII = \frac{Voltage\ Profile\ With\ DG}{Voltage\ Profile\ \ Without\ DG} \quad (1)$$

Where, the voltage profile of the system with DG and without DG are $VP_{w/DG}$ and $VP_{wo/DG}$, respectively, with the same loads at the different load buses. The general expression for VP is given as

$$VP \ = \ \sum_{i=1}^{M} V_i \ L_i \, K_i \quad (2)$$

With

$$\sum_{i=1}^{N} \ K_i = 1 \quad (3)$$

Where from eqn (2) & (3),the voltage magnitude, load and weighing factors are VP, $L_i$ and $k_i$ respectively at bus i in per unit. N is the total number of load buses in the distribution system. As defined, the expression for VP provides an opportunity to quantify and aggregate the importance, amounts, and the voltage levels at which loads are being supplied at the various load busses in the system [11].

## 4.2 Line Loss Reduction index (LLRI)

During the installation of DG it is necessary to keep the line loss reduction index LLRI in mind because it is the major factor of DG. It represents the line losses so for better result it should be minimum as much as possible. Usually line losses are reduced when DG is connected to a distribution system. However, depending on the ratings and locations of DG units, it is possible to have an increase in loss at very high penetration levels. The proposed LLRI is defined as the ratio of total line losses in the system with DG to the total line losses in the system without DG and is expressed as

$$LLRI = \frac{Line\ Loss\ Reduction\ Index\ With\ DG}{Lone\ Loss\ Reduction\ Index\ Without\ DG} \quad (4)$$

Where $LL_{w/DG}$ is the total line losses in the system with the employment of DG and is given as

$$LL_{W/DG} = \ \sum_{i=1}^{M} R_i \ I_{A,i}^2 \, D_i \quad (5)$$

Where $I_{A,i}$ is the per-unit line current in distribution line i with the employment of DG, $R_i$ is the line resistance for line i (pu/km), $D_i$ is the distribution line length (km), and M is the number of lines in the distribution system. Similarly, $LL_{wo/DG}$ is given as

$$LL_{WO/DG} = \ \sum_{i=1}^{M} R_i \ I_{L,i}^2 \, D_i \quad (6)$$

Where $I_{L,i}$ is the per-unit line current in distribution line i without DG. The loads at the different load buses are assumed to be the same for both the cases i.e with and without DG.

## 4.3 Benefit Index (BI)

The BI is a composite index proposed to quantify the overall benefits of DG. There are several benefits offered by DG are explained but only two major ones are considered in this paper: voltage profile improvement and line-loss reduction. Therefore, BI can be formulated as in (7).

$$BI = (BW_{VPI} \times \ VPII\ ) \ + \ \frac{BW_{LLR}}{LLRI} \quad (7)$$

With $\quad 0 \ \leq \ BW_{VPI} \leq 1 \quad (8)$

$$0 \ \leq \ BW_{LLR} \leq 1 \quad (9)$$

and $\quad BW_{VPI} + \ BW_{LLR} = 1 \quad (10)$

Where $BW_{VPI}$ and $BW_{LLR}$ are the benefit weighting factors for voltage profile improvement and line-loss reduction respectively.

In this paper the weight factor is same for each bus and moreover the two indices i.e. VPII and LLRI also have the same weighing factor. However, if DG is installed to mitigate a particular parameter than the corresponding parameter will get higher weight than the other.

# 5. PROBLEM FORMULATION

In this paper an algorithm has proposed by maximizing the value of benefit index (BI) to determine the best location and size of DG. The algorithm has some constraints to obtain proper objective function. The major constraints in the optimization process in the proposed methodology are:

1. The size of DG depends on total system load i.e. the DG size should be less than 10% of the total system load.
2. The DG should not be connected to slack bus.

3. Benefit index (BI) should be maximum.

## 6. PROPOSED ALGORITHM

There is an accumulation of Genetic algorithm and load flow program to develop the proposed algorithm [8], [9], [10]. The flow Diagram is shown in Figure 1. From very starting the load flow is run for the base case of the test system and the results from the load flow is stored in the form of voltage profile at each bus and in the form of total line losses. Then in Genetic algorithm population is initialized and when it satisfied the constraints by means of mutation and crossover, it assign a new generation which set the value for DG size and the bus number to which it is connected for the given iteration and load flow is run by using the value by means of selection. By following this process of crossover, mutation and generation several times the objective function will reach at its maximum value.

## 7. CASE STUDY

IEEE 14 bus test system is selected for as shown in Fig.2. The Table-1 and Table-2 illustrates the line data and the bus data for given test system. The data from given table is used in the MATLAB load flow program. The Case study includes the following steps:

Step 1: Read the line and bus data.

Step 2: Run the load flow and store the results.

Step 3: Run the Genetic algorithm program in MATLAB toolbox.

Step 4: Connect the DG to various buses and update the bus parameters.

Step 5: Run the load flow and calculate the value of Objective function.

Step 6: Repeat all the Step-4 & 5 until the value of objective faction is not maximized.

The GA was run up to 51 iterations, by taking initial range from [0; 1]. The crossover type is kept as scattered and crossover fraction is set to 0.2. The results are synthesized in Table 3 and Figure 3. It can be observed that the bus number 3 represents the most suitable location for the DG by exhibiting maximum value of BI that is 1.19039 with the size of 25.896MW.

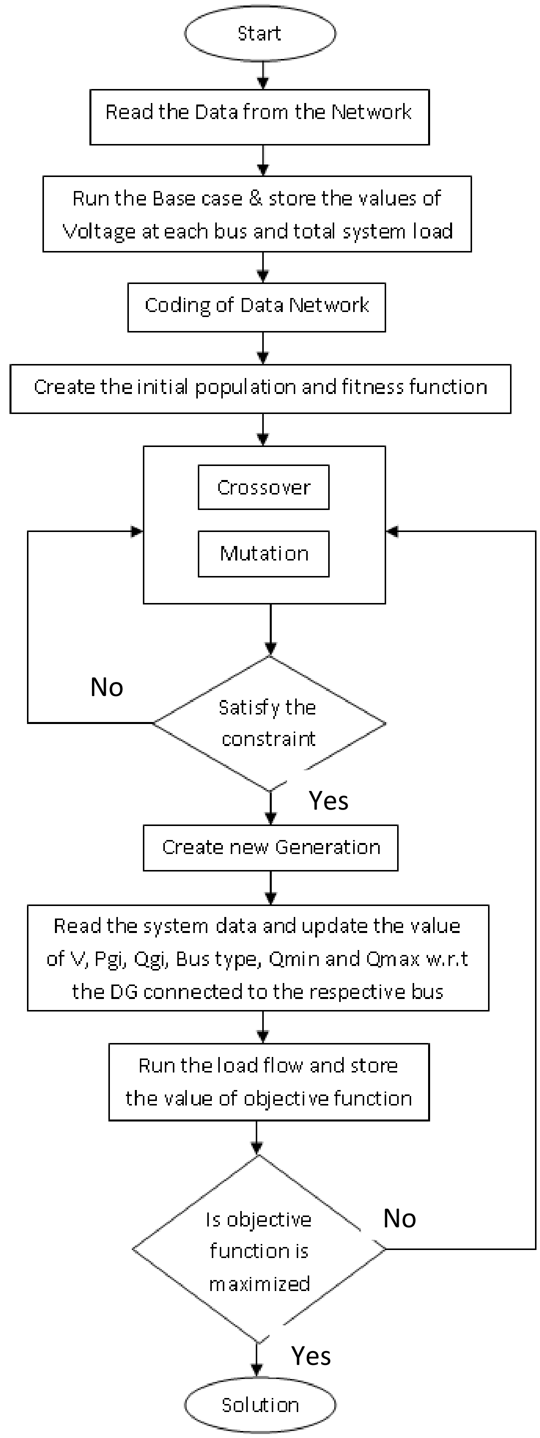


**Fig 1: Flow chart for proposed algorithm**

**Table 1. Line Data for IEEE 14 Bus System.**

| From bus | To bus | $R_{pu}$ | $X_{Pu}$ | B/2 | X' |
|---|---|---|---|---|---|
| 1 | 2 | 0.0194 | 0.0592 | 0.0264 | 1 |
| 1 | 5 | 0.054 | 0.223 | 0.0246 | 1 |
| 2 | 3 | 0.047 | 0.198 | 0.0219 | 1 |
| 2 | 4 | 0.0581 | 0.1763 | 0.017 | 1 |
| 2 | 5 | 0.057 | 0.1739 | 0.0173 | 1 |
| 3 | 4 | 0.067 | 0.171 | 0.0064 | 1 |
| 4 | 5 | 0.0134 | 0.0421 | 0 | 1 |
| 4 | 7 | 0 | 0.2091 | 0 | 0.978 |
| 4 | 9 | 0 | 0.5562 | 0 | 0.969 |
| 5 | 6 | 0 | 0.252 | 0 | 0.932 |
| 6 | 11 | 0.095 | 0.1989 | 0 | 1 |
| 6 | 12 | 0.1229 | 0.2558 | 0 | 1 |
| 6 | 13 | 0.0662 | 0.1303 | 0 | 1 |
| 7 | 8 | 0 | 0.1762 | 0 | 1 |
| 7 | 9 | 0 | 0.11 | 0 | 1 |
| 9 | 10 | 0.0318 | 0.0845 | 0 | 1 |
| 9 | 14 | 0.1271 | 0.2704 | 0 | 1 |
| 10 | 11 | 0.082 | 0.1921 | 0 | 1 |
| 12 | 13 | 0.2209 | 0.1999 | 0 | 1 |
| 13 | 14 | 0.1709 | 0.348 | 0 | 1 |

**Table 2: Bus data for IEEE 14 Bus system.**

| Bus | Type | $V_{sp}$ | $P_{gi}$ | $Q_{gi}$ | $P_{li}$ | $Q_{li}$ |
|---|---|---|---|---|---|---|
| 1 | 1 | 1.06 | 0 | 0 | 0 | 0 |
| 2 | 2 | 1.045 | 40 | 42.4 | 21.7 | 12.7 |
| 3 | 2 | 1.01 | 0 | 23.4 | 94.2 | 19 |
| 4 | 3 | 1 | 0 | 0 | 47.8 | -3.9 |
| 5 | 3 | 1 | 0 | 0 | 7.6 | 1.6 |
| 6 | 2 | 1.07 | 0 | 12.2 | 11.2 | 7.5 |
| 7 | 3 | 1 | 0 | 0 | 0 | 0 |
| 8 | 2 | 1.09 | 0 | 17.4 | 0 | 0 |
| 9 | 3 | 1 | 0 | 0 | 29.5 | 16.6 |
| 10 | 3 | 1 | 0 | 0 | 9 | 5.8 |
| 11 | 3 | 1 | 0 | 0 | 3.5 | 1.8 |
| 12 | 3 | 1 | 0 | 0 | 6.1 | 1.6 |
| 13 | 3 | 1 | 0 | 0 | 13.5 | 5.8 |
| 14 | 3 | 1 | 0 | 0 | 14.9 | 5 |

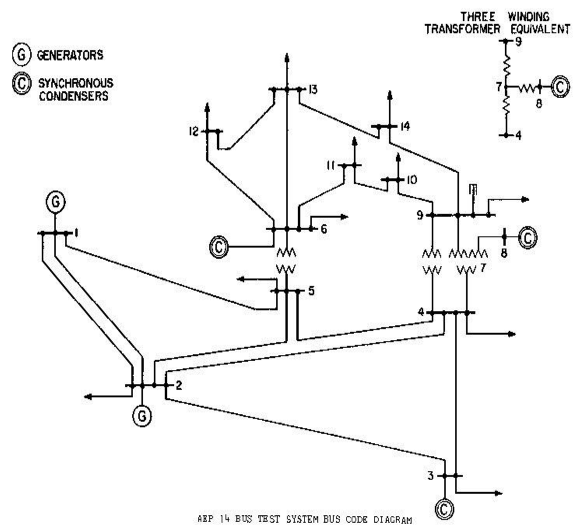


**Fig 2. Single line diagram of 14 bus system**

By comparing the results with classical algorithm [11] it can be observed that the GA represents better value for BI than that of classical algorithm. As in classical algorithm it gives bus number 3 is the best location for DG with the size of 25.9MW with the benefit index of 1.1867 which is less than the results from GA. The results from GA are shown in fig.3. The two variables are used in genetic algorithm. The first variable is DG location i.e. the bus no. with which DG is connected and the second variable is DG size. Two constraints are defined for the given system. First constraint is the DG location i.e. it should not be connected with slack bus (bus no. 1) and the second constraint is DG size which should be less than 10% of the total system load(25.9 MW).

**Table 3: Results from GA for Given tests system**.

| | |
|---|---|
| Bus location | 3 |
| DG size | 25.896MW |
| Losses | 10.36792 MW |
| VPII | 1.00939 |
| LLRI | 0.76274 |
| BI | 1.19039 |

**Table 4: Comparison of results of Classical Algorithm and Genetic Algorithm**

| Algorithm | Bus Location | DG size | VPII | LLRI | BI |
|---|---|---|---|---|---|
| **Classical** | 3 | 25.9 MW | 1.000001 | 0.762708 | 1.1866 |
| **Genetic** | 3 | 25.896 MW | 1.00939 | 0.76274 | 1.19039 |

## 8. CONCLUSION

To explain how maximize the benefits of DG by choosing the optimal sizing and optimal location of DG through genetic algorithm. The outcome of the proposed algorithm is compared with the outcome of classical algorithm approach which is used to justify the impact of DG sizing and allocation on distribution system. Simulation results for the given system shows that the DG has great impact on VPII and LLRI, which has been assigned as DG benefits. Through observation it is clear that VPII and LRII are affected heavily through the DG size and location. So there is a need to determine DG location and size. By comparison it can be found that the GA technique gives the best results than that of classical algorithm technique for the sizing and location of DG.

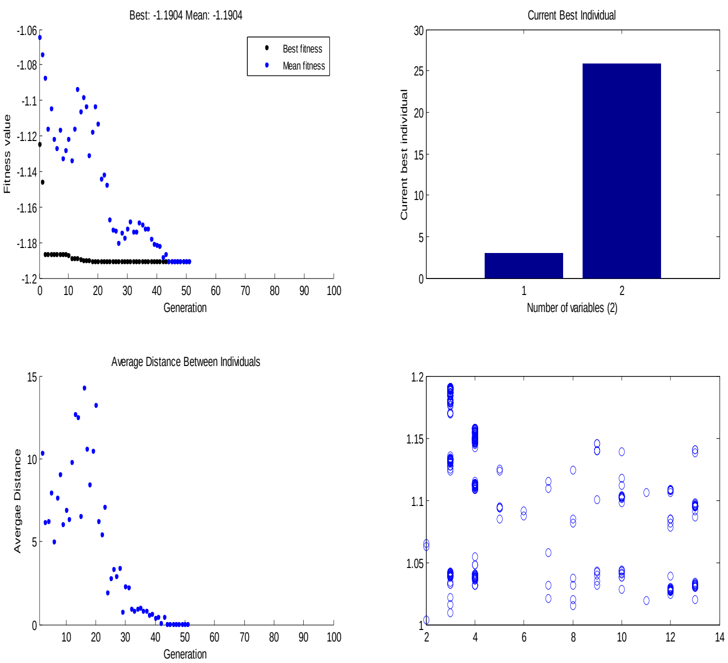


**Fig 3. Results from Genetic Algorithm**

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