# Computational Intelligence Technique for DG Installation Within Contingency Scenario

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***Abstract*— Distributed Generator (DG) had created a challenge and an opportunity for developing various novel technologies in power generation. DG is installed to improve the voltage profile as well as to minimize losses. DG allocation is a crucial factor in distribution loss management. The optimum DG allocation provides a variety of benefits. This paper presents a computational intelligence technique for DG installation within contingency scenario. A contingency scenario study of DG deployment in the distribution network for reducing real power losses has been considered and evaluated. The Artificial Bee Colony (ABC) algorithm technique for solving the problem of optimal location and sizing of DG on distributed systems is presented. The objective is to minimize transmission power loss under the contingency scenario. This proposed technique will be compared with Evolutionary Programming (EP) algorithm, that usually designed to maximize or minimize the objective function, which is a measure of the quality of each candidate solution. Meanwhile, for ABC algorithm is inspired of the intelligent behavior of bees during the nectar search process. This operational coding was developed in MatLAB and conducted on the test system, that is IEEE 69-bus radial distribution system.**

**Keywords-Distributed Generation(DG), ABC Algorithm, loss reduction, radial distribution system, sizing of DG, location of DG.**

## I. Introduction

Distributed generation (DG) is not a new concept, it bears a cardinal role in the electric power system organization and market. DG mainly depends upon the facility and performance of a portfolio of small size, compact, and clean electric power generating units at or near an electrical load (distribution area). Unlike traditional generation, the aim of DG is to generate part of required electrical energy on small scale closer to the places of utilization and interchanges the electrical power with the network [1].

Electrical experts had been recognized about the complementary and coordination between greater power grid and DG as an optimal operation mode to reduce energy consumption [2], to save investment and to improve the reliability and flexibility of power supply. The placement of DG in distribution feeders is exposed to have an impact on the operations and control of power system, a system designed to operate with large, central generating facilities. It may be disguised in simpler term as small-scale electricity market.

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One advantage of deploying a DG-unit in distribution networks is to reduce the total system real power loss while satisfying certain operating constraints. The problem of DG-unit application can be interpreted as finding the optimal size and location of that DG-unit to minimize the system total power loss.

In order to required to the demanded layer of load demand, DG units are incorporated in the distribution network to minimize power loss, to provide reliable and uninterrupted power supply and also to accomplish economic benefits such as improve the electric potential profile, energy efficiency and load leveling. It causes as well, some extra advantages like environmentally friendly..

Some authors have used the analytical techniques for optimal allocation of DG in terms of different load types. The references have applied power flow algorithms optimal DG placement at each load bus; such that DG can be placed at every load bus. Moreover, many authors have applied the evolutionary computational techniques for finding the optimal location and size of DG. The Genetic algorithm (GA), Evolutionary programming (EP), Decision Theory, Fuzzy systems, Ant Colony optimization (ACO), Particle Swarm optimization (PSO),Tabu search (TS), Differential Evolution, Immune algorithm based optimization (IA) , and Artificial Bee Colony optimization algorithm (ABC) have come to be the most widely used tools for solving optimal DG allocation problem [3].

Many advances have been aimed to resolve the problem of defining the optimal placement and sizing of distributed generation (DG) in order to get the highest benefit of DG using evolutionary algorithms (EA). References [4-6] presents the method to identify the optimal location and sizing of DG in order to minimize the total distribution losses and improve the voltage profile in the system. EA operate on a population of potential results, utilizing the rules of endurance of the fittest to produce successively better approximations to a resolution. At each generation of the EA, a new lot of approximations are created by the operation of selecting individuals according to their fitness in the problem domain and reproducing them using variation operators [7].

In the reference in [8], the author proposed minimizing power loss by holding the optimal size, location and operation point of the DG-unit. A sensitivity analysis relating the power loss with respect to DG-unit current injection was used to key out the DG-unit size and performance level. The suggested method was tried out for constant electrical resistance and a constant current model. One of the test systems assumed that loads were uniformly spread, which is rare in practical feeder systems. The arrangement of the DG-unit was based on the assumption of downstream load buses, which may not be appropriate for different feeder configurations.

The authors of [9] proposed the GA for optimal power flow (OPF) to minimize the DG-unit's active and also reactive power cost. Two examples of DG-unit optimization cases were considered, with and without reactive power injection. Significant reduction in the search space was attained by eliminating the DG-unit size. Still, DG-unit dispatching can cause operational problems in the distribution feeders.

In this paper, an artificial bee colony (ABC) algorithm to determine the optimal DG-unit's size and location in order to minimize the total system real power loss is proposed. Sample feeder systems are examined, as well as various test cases. The results reveal that the evolutionary programming (EP) is efficient and capable of handling complex optimization problems rather than using the ABC algorithm.

## II. METHODOLOGY

The test system taken for optimal allocation of DG units is IEEE 69 bus radial distribution system. Initially the Newton Raphson Load flow is applied to the IEEE 69 bus radial distribution system with injected DG at bus number 5 with reactive power load equals to 15MVar and total loss is found. Then to reduce the total real power loss of the radial distribution system, optimal allocation and sizing of Distributed Generation (DG) using Evolutionary Programming (EP) and Artificial Bee Colony (ABC) Algorithm is done. Here two different types of DG's and range in size are considered for allocation. DG 1 is for photovoltaic energy type with panels range from less than 5 kW and DG 2 is for wind turbine system energy type with range in size from less than 5 to over 1000kW. Optimal size and location of DG is given by the bus that provides minimum power loss after DG penetration. To create a contingency scenario on this project, by changing reactive power on the load on bus number 5 of the system is necessary by minimum value equal to 15Mvar with increment value 15 for six times. At the end of the project, the result from both techniques was compared due to the minimization power losses. The followings are the method used for this project to achieve the objective:

### *a)* Evolutionary Programming (EP)

Evolutionary Programming (EP) is a stochastic optimization strategy emphasis on the behavioral linkage between parents and their offspring [10]. In the initialization process, random number generation is involved. The EP also involved fitness calculation, statistic, mutation and selection. The overall EP process is represented in Figure 1.

A series of random number is generated using a uniform distribution number for the initialization process is conducted. For the optimal sizing of Distributed Generation (DG) problem, the random number represents the size and location of DG to be installed in the system. The number of variables depends on the number of DG either one (for single DG installation) or five (for multiple DG). These variables will be assigned as the active load $(x_i)$ with negative sign. Some constraints must be set at the beginning, so that the EP will only generate random numbers that satisfy some predetermined conditions such as the total losses (fitness) should be less than total losses without DG.

In this work, a 20 series of random number is generated using a uniform distribution number for the initialization process is conducted. This project starts with assigning injected DG with value equal to 15MVar on the reactive power system load for the real power to the load set to be at bus number 5. There have 4 variables represent two types of location $(x_1)$, $(x_3)$ and sizing $(x_2)$, $(x_4)$ of DG each. Then, all the variables will be assigned as the active load with a negative sign. To satisfy some predetermined condition, the system was set with the constraint to be the total losses (fitness) will be lesser than total losses without DG.

Mutation is performed on the random number, $(x_i)$ to produce offspring. The mutation process is based on the following equation:

$$x_{i+m,j} = x_{i,j} + N\left(0, \beta\left(x_{j\,max} - x_{j\,min}\right)\left(\frac{f_i}{f_{max}}\right)\right) \qquad (1)$$

Where:
$x_{i+m,j}$ = mutated parents(offspring)
$x_{i,j}$ = parents
$N$ =Gaussian random with mean $\mu$ and variance $\gamma^2$
$\beta$=mutation scale, 0< $\beta$ <1
$f_i$=fitness for ith random number
$f_{max}$=maximum fitness

The mutation process produced the offspring are merged with the parents to undergo a selection. The process is required in order to identify the candidates that have a chance to be transcribed into the next generation. The main objective of the project is to minimize power loss, so that the population will be ranked in ascending order.

. The first half population acted as the new generation. To satisfy the termination criterion, the difference between the maximum and minimum fitness for the program is specified to be less than 0.0001. If the convergence condition is not satisfied, the mutation, competition and selection processes will be repeated again until a convergence criterion is met.

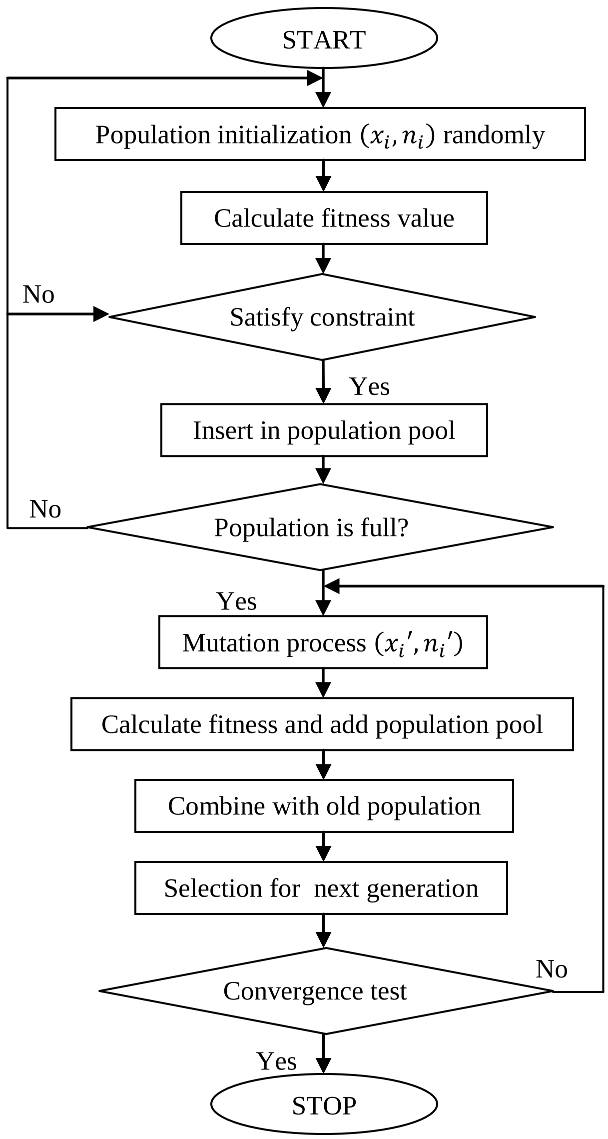


Figure 1: Flowchart for EP

*b) Artificial Bee Colony (ABC)*

*i. Algorithm*

In a real bee colony, some projects are performed by specialized individuals using specialized bees. The aim of the individuals is to maximize the nectar amount stored in the hive using efficient division of labor and self-organization. The ABC algorithm is an optimized algorithm which simulates the foraging behavior of a bee colony as stated by Karaboga [11] in 2005 for real parameter optimization.

Honey bee swarm categorized of three kinds of bees: employed bees, onlooker bees and scout bee [12]:

- Employed bees: Searching for the food source position (solution) randomly and then perform a "waggle dance" in front the bees waiting in the hive to share the information that is the nectar amount. The period of the dance depends on the nectar amount (fitness value) of the food source.
- Onlooker bees: Decide the best food source position according to the highest quality of that food source by watching dances of various employed bees.
- Scout bees: An employed bee of the source which is abandoned becomes a scout and starts to search a new food source randomly.

In the proposed algorithm the position of food source represents a possible solution to the optimization problem. While, the nectar amount of a food source corresponds to the profitability (fitness) of associated solution. One employed bee represents each food source is exploited. In the other hand, the number of employed bee is equal to the number of food sources existing around the hive (number of solutions in the population). The employed bee change becomes a scout bee because of the employed bee whose food source has been abandoned.

*ii. ABC Algorithm For DG-Unit Application Problem*

Figure 2 shows the flow chart of the ABC algorithm. The solution steps of the proposed ABC algorithm in the DG-unit application to minimize the real power losses in the system are described in following:

1. Food-source positions were initialized (solutions population), where $i = 1,2, \dots, E_b$. The $X_i$ solution form is as follows.
2. Read system data which contain bus and line data of the test system.
3. Run Newton Raphson Load Flow technique
4. Calculate the food source amount of the population by means of the fitness values using:
$$fitness_i = \frac{1}{1+Obj.fun_i} \quad (2)$$
Where $Obj.fun_i$ represents the response of real(SLT) at a solution.
5. Select a new population of employed bees
6. Produce neighbor solutions for the employed bees
7. Calculate the probability $P_i$values (fitness 1) for the $X_i$solutions using:
$$p_i = \frac{fitness_i}{\sum_{i=0}^{E_b} fitness_i} \quad (3)$$
8. Apply the greedy selection process.
9. If all onlooker bees are distributed, go to Step 5. Otherwise, go to the next step.
10. The maximum number of patches is selected
11. Calculate the global probability $P_{i_global}$values(fitness 2) for the $X_i$solutions using (2).
12. Memorize the best solution attained so far.
13. Stop and print result of optimal solution based on the highest value of global probabilities.

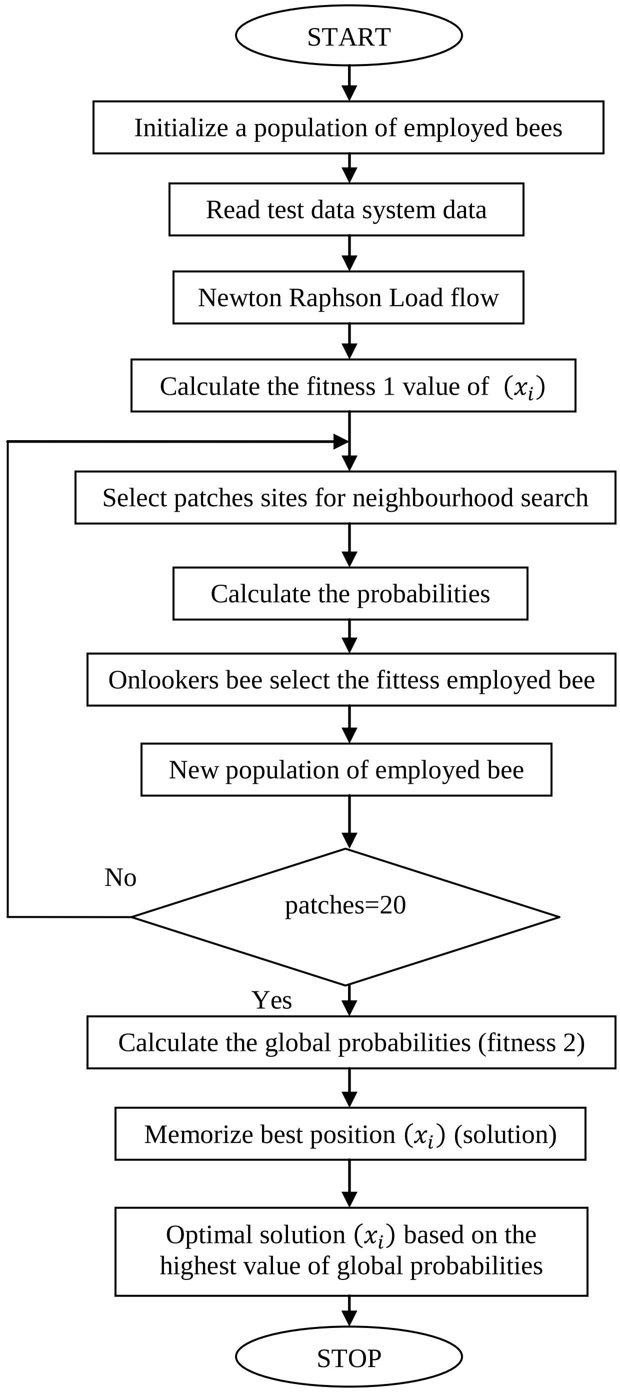


Figure 2: Flowchart of ABC

## III. RESULT AND DISCUSSION

### *A. Power Loss without DG* and with DG

Initially, the Newton Raphson load flow of IEEE 69 bus radial distribution system was performed and the loss found and recorded in Table 1. The real power loss without DG in the system is given by P loss respectively. Then two different types of distributed generators were optimally allocated and sized using Evolutionary Programming and Artificial Bee Colony Algorithm and the loss was found by the Newton Raphson method. The new loss value with injected with DG is recorded in Table 1. The real power loss within DG in the system is given by P loss respectively.

Table 1: Power loss without and with DG

| **Test IEEE System Data** | **P loss (MW)** | | |
|---|---|---|---|
| | **Technique** | **Without DG** | **With Dg** |
| **69-bus** | **EP** | 0.4957 | 0.4237 |
| | **ABC** | 0.4957 | 0.4917 |

### *B. Optimal DG location and size*

The both techniques are used to find the optimal location and size of two DG within the size limit of (0 – 5) kW for DG 1 (photovoltaic) and (5 – 50) kW for DG 2 (wind turbines). The data system is recorded in Table 2. All possible combinations of DG interconnections are tried at varying sizes using EP and ABC technique. The best combination that gives minimum power loss in the IEEE 69 bus radial distribution system is taken as the optimal solution for DG allocation.

Table 2: Optimal DG location and size

| **Technique** | **Location (Bus)** | | **Sizing (kW)** | |
|---|---|---|---|---|
| | **DG 1** | **DG 2** | **DG 1** | **DG2** |
| **EP** | 35 | 3 | 3.6548 | 7.5778 |
| **ABC** | 16 | 27 | 1.4123 | 15.4062 |

DG 1 and DG 2 are the two distributed generators considered for allocation in the IEEE 69 bus radial distribution system. The optimal locations of DG 1 and DG 2 for EP are on buses 35 and 3 respectively, meanwhile for ABC are at buses 16 and 27 respectively . The optimal sizes of DG 1 and DG 2 for EP are 3.6548kW and 7.5778kW respectively, meanwhile for ABC are 1.4123kW and 15.4062kW respectively at IEEE 69-bus test system.

Table 3: Comparison of results

| **Technique** | **P loss at 69-bus (MW)** | |
|---|---|---|
| | EP | ABC |
| **Before DG Placement** | 0.4957 | 0.4957 |
| **After DG Placement** | 0.4237 | 0.4917 |
| **Nett loss reduction** | 0.072 | 0.004 |
| **Percentage (%)** | 14.52 | 0.81 |

Initially, the Newton Raphson load flow of the test system was performed before allocation of DG and the loss was found to be 0.4957 MW at IEEE 69-bus test system. Then a distributed generation (DG) was optimally allocated and sized using Evolutionary Programming and Artificial Bee Colony such that the loss is minimized after DG penetration and the loss was found to be 0.4237MW and 0.4917MW at IEEE 69-bus test system. Thus a total real power loss reduction of 0.072MW for the EP, meanwhile total real power loss reduction of 0.004MW for ABC at IEEE 69-bus test system was obtained as shown in Table 3. Based on table 3, show that EP is able to produce better results in term fitness (loss minimization) comparable to ABC according to the higher percentage of nett loss reduction.

### *C. The* Contingency Scenario

a) Evolutionary Programming

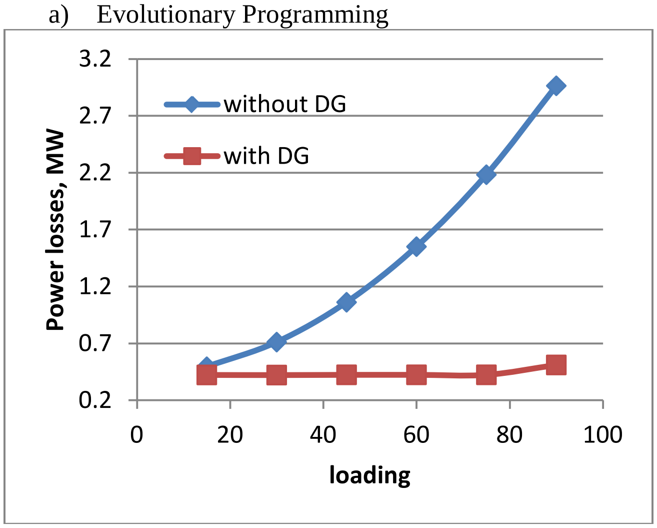


Figure 3: Comparison of total power losses for overall load increase in the system.

b) Artificial Bee Colony Algorithm

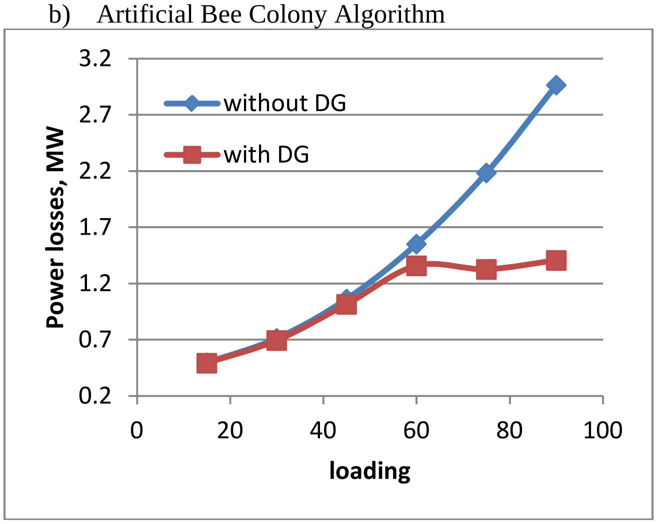


Figure 4: Comparison of total power losses for overall load increase in the system.

To represent as the contingency scenario for this project, by changing reactive power on the load on bus number 5 of the system is necessary by minimum value equal to 15MVar with an increment value equal to 15 for six times will be accepted. The results of power losses are recorded for both techniques. Figure 3 and figure 4 shows that the installation of DG with an increment of load at bus 5 compare to losses within the case without any installed of DG. Within the changes make in the system by changing reactive power on the load, result from EP in figure 3 proves that the nett power loss reduction is higher than result from ABC in figure 4.

## IV. CONCLUSION

In this paper, the real power loss of IEEE 69 bus radial distribution system has been reduced by optimal allocation of Distributed Generation (DG) using Evolutionary Programming and Artificial Bee Colony Optimization technique. The proposed algorithm that usually designed to maximize or minimize the objective function, which is a measure of the quality of each candidate solution for EP and for ABC algorithm is inspired of the intelligent behavior of bees during the nectar search process. In the end, both of the algorithm was compared due to the power losses. The results revealed that EP produces better results in terms (loss minimization) compared to ABC based on the nett loss reduction of the EP is higher than ABC.

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