

# Optimal Placement of Distributed Generation Using Bacterial foraging Optimization in an Electrical Distribution System

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**Abstract-** Distributed generation (DG) has been placed in electrical distribution networks widely due to line loss reduction, environmental benefits, better voltage profile, postponement of system upgrading, and increasing reliability. Optimization techniques are tools which can be used for placement and sizing of the DG units in the distribution system. The impacts of DG placement issues, such as power loss minimization and voltage profile, should be analyzed effectively by proposing a method of locating and sizing DG units. This paper proposes Bacterial Foraging Optimization (BFO) algorithm technique for optimal placement of DG units in Distribution System (DS) to minimize the total real power loss, improve power factor and to regulate the voltage profile. BFO is a recently developed nature-inspired optimization technique, which is based on the foraging behavior of *E. coli* bacteria. To determine the validity of the BFO algorithm, a standard IEEE 69 bus radial distribution feeder system is examined with two test cases. The results show that the proposed BFO algorithm is more efficient, and capable of handling mixed integer nonlinear optimization problems effectively.

**Keywords-** Distributed Generation, Optimal DG size, Bacterial Foraging Optimization (BFO), *E. coli*, DS.

## NOMENCLATURE

$S_{Load,k}$  Apparent load power at bus k  
 $S_{system j,k}$  System apparent power flows from bus j to bus k  
 $S_{system k,j}$  System apparent power flows from bus k to bus j  
 $S_{rated j,k}$  Apparent rated power flows from bus j to bus k

$S_{rated k,j}$  Apparent rated power flows from bus k to bus j  
 $S_{system,k}$  Apparent load power at bus k  
 $P_j$  Active power flows from bus j to bus k  
 $Q_j$  Reactive power flows from bus j to bus k  
 $N$  Number of buses  
 $V_j$  Bus voltage at bus j  
 $V_k$  Bus voltage at bus k  
 $A P_k$  Active power injected bus k  
 $R P_k$  reactive power injected bus k  
 $L_j$  Load demand at bus j  
 $S_{j,k}^{sys}$  System apparent power flows from bus j to bus k  
 $V_{max}^{spec}$  Maximum specified allowable voltage  
 $P_{DGj}$  Dispatchable DG rated active power at bus j  
 $Q_{DGj}$  Dispatchable DG rated reactive power at bus j  
 $r_k$  Line resistance connecting buses j and k  
 $x_k$  Line reactance connecting buses j and k  
 $\mu_p$  Real power multiplier when there is no real power source set active power multiplier to 0 or when there is real power source set to 1  
 $\mu_q$  Reactive power multiplier when there is no real power source set active power multiplier to 0 or when there is real power source set to 1  
 $S_{max}^{DG}$  Maximum DG unit size in KVA  
 $S_{min}^{DG}$  Minimum DG-unit size in KVA  
 $p.f_{max}^{DG}$  Maximum DG unit's working power factor  
 $p.f_{min}^{DG}$  Minimum DG unit's working power factor

### I. INTRODUCTION

With the increasing level of global warming due to emissions of CO<sub>2</sub>, renewable based distributed generation (DG) should play a major role in electrical power generation. DG may be defined as a small scale generating resource, placed near to load being served or at low voltage distribution side [1]. DG refers to small sources ranging between 1 kW and 50 MW, which are normally placed close to consumption centers. In general DS is designed for one-way power flow. The insertion of DG in the DS violates this basic assumption and can disrupt distribution operation if not carefully employed, potentially causing islanding, protection disturbances, upset voltage regulation, and other power quality problems. DG normally follows the utility voltage and injects a constant amount of real and reactive power [3].

The optimal placement and sizing of DG units on the DS has been analyzed to achieve various solutions. The objective was the minimization of the active losses of the feeder or the minimization of the total network supply costs, which includes generators operation and losses compensation or even the best utilization of the available generation capacity. A stochastic multi-objective model for placement of DG in electrical distribution networks is proposed in [13] with a binary particle swarm optimization (PSO) algorithm. The DS expansion planning strategy with DG systems with intermittent power generation is presented in [14] to obtain optimal solutions for system planners. A DG placement planning study framework is brought in [15] that includes a coordinated reconfiguration feeder and voltage control to calculate the maximum allowable DG capacity at a given node in the electrical distribution system. Works have been dealing with the DG optimal placing and sizing problem by means of multi-objective optimization (MOO) tools, with a considerable number of them based on heuristic approach. Some basic concepts about MOO are introduced in order to support the methods comprehension. The MOO consists in minimize or maximize simultaneously a set of objectives subject to a number of constraints. The process of optimization in a multi-objective scenario occurs in two stages: the determination of the solution set, where all objective function values of each solution cannot be enhanced at the same time and the human decision making whose criteria can be applied before, after or even during the optimization process.

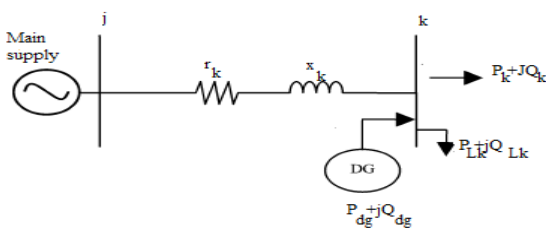


Fig. 1: Sample two-bus system with one DG

In [16] a distributed micro grid model has been introduced to optimize best location and the capacities within DG micro grid, in which wind power and photovoltaic power are taken into consideration with both PSO and Elitism Genetic Algorithm (EGA). A multi-objective index-

based approach for optimal location of DG and determining the size of DG units in electrical distribution systems with different load models based on PSO is introduced in [17,18] and a combined genetic algorithm is presented in [19] for optimal location and sizing of DG on DS. A methodology for evaluating the impact of DG-units on power loss, reliability, and voltage profile of distribution networks was presented in reference [11].

A heuristic approach for optimal location and size of DGs in distribution networks, with the objectives of minimizing the power loss and voltage profile improvement is proposed in [6]. In [10] a Newton-Raphson algorithm based load flow program is used to solve the load flow problem. Moreover, some heuristic search requires exhaustive search for all possible locations which may not be applicable to more than one DG.

As a contribution to the methodology for DG placement analysis, in this paper it is proposed a BFO algorithm for the allocation of distributed generators in distribution networks, in order to improve voltage profile and line loss reduction in DS. The organization of this paper is as follows. Section II addresses the problem formulation. Section III addresses the impact of the DG placement and size on DS. The BFO algorithm is represented in Section IV. Pseudo code for a BFO computation procedure for the problem is given in Section V. Simulation result on the test systems are illustrated in Section VI. Then, the conclusion is given in Section VII.

### II. PROBLEM FORMULATION

Importance of placing a DG in distribution networks is to reduce the total system real power loss while satisfying certain operating constraints. In other words, the problem of DG application can be interpreted as determining the optimal placement and size of the DG to satisfy the desired objective function subject to equality and inequality constraints. Reliability, accuracy, and flexibility of the DG solution algorithm are influenced by the load flow analysis used. So the overall algorithm accuracy is highly depends on that analysis. It can be otherwise called that the load flow analysis is the heart of the DG-unit solution algorithm. Based on that the load flow algorithm used in [10] is applied in this paper. In Fig.1, a sample two bus system including DG-unit is considered. The mathematical formulations of the mixed integer nonlinear optimization problem for the DG-unit application are as follows: [9]

The objective function is to reduce the real power loss

$$Obj.Fun = \min \left( \sum_{j=0}^n \frac{P_j^2 + Q_j^2}{V_j^2} \right) * r_k \text{ ----- (1)}$$

The equality constraints are the three nonlinear recursive power-flow equations describing the system [10]

$$P_j - r_k \frac{(P_j^2 + Q_j^2)}{V_j^2} - P_{Lk} + \mu_p A P_k - P_k = 0 \text{ ----- (2)}$$

$$Q_j - x_k \frac{(P_j^2 + Q_j^2)}{V_j^2} - Q_{Lk} + \mu_q R P_k - Q_k = 0 \text{ ----- (3)}$$

$$V_k^2 = V_j^2 - 2(r_k P_j + x_k Q_i) + \frac{(r_k^2 + x_k^2)(P_j^2 + Q_j^2)}{V_j^2} \text{----- (4)}$$

Where  $i=0, 1, 2, \dots, n$

The inequality constraints are the system's voltage limits, that is, +5% or - 5% of the nominal voltage value

$$V_{min}^{spec} \leq V_j^{sys} \leq V_{max}^{spec} \text{----- (5)}$$

In addition, the thermal capacity limits of the network's feeder lines are treated as inequality constraints

$$S_{j,k}^{sys} \leq S_{j,k}^{rated} \leq S_{k,j}^{sys} \text{----- (6)}$$

The discrete inequality constraints are the DG-unit's size (KVA) and power factor

$$S_{max}^{DG} \geq S_j^{DG} \geq S_{min}^{DG} \text{----- (7)}$$

$$p \cdot f_{max}^{DG} \geq p \cdot f_j^{DG} \geq p \cdot f_{min}^{DG} \text{----- (8)}$$

The power factors of DG are set to operate at practical values [27], that is, from unity to 0.85 towards the optimal result. The operating DG-unit's power factor whether lagging or leading must be dissimilar to the bus's load at which the DG-unit is placed [26]. Consequently, the net total of both active and reactive powers of that bus where the DG-unit is placed will also decrease.

### III. IMPACT OF THE DG PLACEMENT AND SIZE ON DISTRIBUTION SYSTEM

The placement of DGs renders a group of advantages, such as economic, environmental, and technical. The economic advantages are the reduction of transmission and distribution costs, reduction of electricity price, and saving of fuel. Environmental advantages entail reductions of sound pollution and emissions of greenhouse gases. The technical benefits of DGs in existing networks are minimizing power losses, reducing the emission of pollutants, improving power quality, and relieving transmission and distribution congestion [4]. It can also provide stand-alone remote applications with the required power. Therefore, the optimal placement and sizing of DGs attract active research interest.

Several researchers have worked in this area [7-13]. DGs are placed at optimal locations to reduce losses [7]. Some researchers have presented load flow algorithms to find the optimal size of DGs at each load bus [8, 9]. Wang and Nehrir have shown analytical approaches for optimal placement of DGs in terms of loss [10]. Chiradeja quantified the benefit of reduced line loss in a radial distribution feeder with a concentrated load [11]. Further, many researchers have used evolutionary computational methods for finding the optimal DG placement [14-19]. Mithulananthan used a genetic algorithm (GA) for placement of DGs to reduce the losses [15]. Celli and Ghiani used a multi objective Evolutionary algorithm for the sizing and placement of DGs [18]. Nara et al. used a tabu search algorithm to find the

optimal placement of DGs [19]. Since the analytical methods are generally poor to solve this type of function, almost many of the related papers are based on heuristic methods. Due to the discrete nature of the sizing and placement problem, the objective function has a number of local minima. The hybrid particle swarm optimization (HPSO) algorithm has applied as a useful tool for engineering optimization, to solve complex optimization problems [10-15]. This paper presents a novel search approach with respect to the voltage profile for the optimal placement of DGs using the BFO algorithm and compares it with the Bee colony optimization (BCO) algorithm and other methods. Optimal bus locations are determined to obtain the best objective. The multi objective optimization simultaneously covers the optimization of both the voltage margin and active power loss. The problem is defined and the objective function is introduced to maximize the voltage profile index, and minimize losses. Hence, an algorithm is developed to assess the voltage profile based on the loadability limit. This method is executed on the IEEE 69 bus test systems, showing the robustness of this method in finding the optimal sizing and placement of DGs, efficiency for improvement of voltage profile, power factor improvement and reduction of system real power losses [14].

### IV. BACTERIAL FORAGING OPTIMIZATION IMPLEMENTATION

The BFO algorithm was first represented by Pasino in 2002. The idea in this method was adopted from biological and physical living behavior of *E. coli* bacteria existing in human intestine. This algorithm has three main processes namely Chemotaxis, Reproduction and Elimination fault Dispersal. When *E. coli* grows, it gets longer, and then divides in the middle into two "daughters." Given sufficient food and held at the temperature of the human gut of 37 ° C, *E. coli* can synthesize and replicate everything it needs to make a copy of itself in about 20 min; hence growth of a population of bacteria is exponential with a relatively short time to double. The *E. coli* bacterium has a guidance system that enables it to search for food and try to avoid noxious substances. The behavior of the *E. coli* bacterium, will be explained as its actuator (the flagellum), "decision making," sensors, and closed-loop behavior. This section is based on the work in [24, 25]. Fig 2 shows the simplified BFO optimization flowchart.

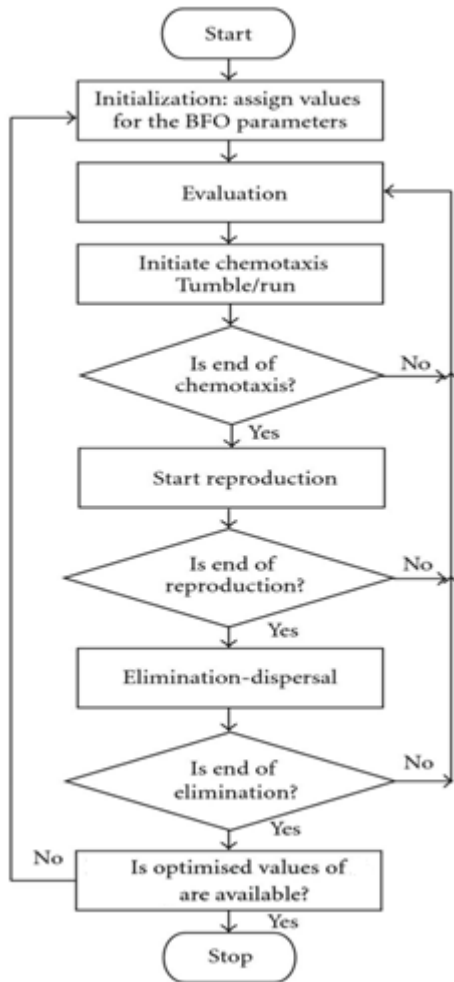


Fig 2.Simplified BFO optimization flowchart

(i) Chemotaxis: An *E. coli* bacterium can decide to move in two different ways depending on its environment. A bacterium is subject to change during its lifetime between the two ways of swimming (swim for a short time) and tumbling. In BFO, one moving unit length with random directions represents tumbling and one moving unit length with the same direction relative to the final stage represents swimming. The mathematical equation for

Chemotaxis is expressed as follows:

$$\theta^i(j + 1, k, l) = \theta^i(j, k, l) + C(i) \frac{\Delta(i)}{\sqrt{\Delta^T(i)\Delta(i)}} \dots (9)$$

Where

- $\theta^i$  : location of  $i^{\text{th}}$  bacterium
- $C(i)$  : movement length
- $\Delta(i)$  : direction random vector
- $j$  : is representing  $j^{\text{th}}$  chemotaxis
- $k$  : is representing  $j^{\text{th}}$  reproduction
- $l$  : is representing  $j^{\text{th}}$  elimination and dispersal

also, the number of chemotaxis is represented by  $N_C$ .

(ii) **Reproduction:** After the number of  $N_C$  Chemotaxis steps, reproduction step takes place.  $N_{re}$  represents the number of reproduction steps.

(iii) Elimination-Dispersal: The swimming process prepares the conditions for local search and reproduction process speeds up the convergence. In a large space swimming and reproduction for searching global optimal point cannot be sufficient. In bacterial foraging, dispersion takes place after a definite number of reproduction processes. A bacterium is selected with regard to a prearranged probability of  $P_{ed}$  to be dispersed in the environment and moved to another position. These events can effectively prevent trapping in local optimal point.  $N_{ed}$  is the number of elimination and dispersal phenomenon and  $P_{ed}$  is defined for every bacterium with the probability of elimination and dispersal. A flowchart for BFO algorithm by MATLAB Programming is shown in Figure 2.

V. PSEUDO CODE FOR BFO ALGORITHM:

Step (1): Initialize the parameters,

- S: Total number of bacteria
- P: Number of parameters to be optimized
- $N_c$ : Number of chemotactic steps
- $N_s$ : Number of swarming,
- $N_{re}$ : Number of reproduction steps
- $N_{ed}$ : elimination-dispersal steps
- $d_{attract}$ ,  $W_{attract}$ ,  $d_{repellant}$ ,  $W_{repellant}$  :  
Attractant and repellant values
- $P_{ed}$  : Probability of elimination- dispersal
- $C(i)$  : step size

step(2): Elimination-Dispersal loop  $l = l + 1$

step(3): Reproduction loop  $k = k + 1$

step(4): Chemotactics loop  $j = j + 1$

step(5): Every bacterium  $i = i + 1$

[a] Compute fitness function  $J(i,j,k,l)$

Let,  $J(i, j, k, l) = J(i, j, k, l) + J_{cc}$

[b] Let,  $J(\text{last}) = J(i,j,k,l)$  to save this value. we may find a better cost via a run.

[c] Tumble: Generate a random vector  $\Delta(i)$  such that  $1 \leq \Delta(i) \leq -1$ .

[d] Move: Let,  $\theta^i(j+1,k,l) = \theta^i(j,k,l) + C(i) * (\Delta(i) / \sqrt{(\Delta^T(i) * \Delta(i))})$

[e] Compute  $J(i,j+1,k,l)$  and let,  $J(i,j,k,l) = J(i,j,k,l) + J_{cc}$

[f] Swim: Let,  $m = 0$ . (counter for swim length)  
 (i) While  $m < N_s$   
 (ii) Let,  $m = m + 1$   
 (iii) if  $J(i, j+1, k, l) < J(i, j, k, l) = J(i, j, k, l) + J_{cc}$  then  
 Let,  $J_{last} = J(i, j+1, k, l)$   
 $\theta^i(j+1, k, l) = \theta^i(j, k, l) + C(i) * (\Delta(i) / \sqrt{(\Delta^T(i) * \Delta(i))})$

(iv) else, let  $m = N_s$   
 [g] Go to next bacterium, if  $i \neq S$   
 Step(6): if  $j < N_c$ , go to step(4)  
 Step(7): Reproduction:

[a] for the given  $k$  and  $l$ , and for each  $i = 1$  to  $S$ ,  
 (i) Let,  $J_{health} = \sum_{i=1}^{N_c} J(i, j, k, l)$   
 (ii) Sort the fitness in ascending order  
 [b] The  $S_r$  bacteria with worse health value will die, the remaining  $S_r$  bacteria with best values will split into two.  
 Step(8): if  $k < N_{re}$ , go to step(3)  
 Step(9): Elimination-Dispersal  
 [a] for  $i = 1$  to  $S$ , with probability  $P_{ed}$ , eliminate and disperse each bacterium.  
 [b] if a bacterium eliminated, then add new one to a random location on the search space.  
 Step (10): if  $l < N_{eds}$ , go to step (2), Else Terminate.

VI. RESULTS AND DISCUSSION

The proposed BFO algorithm is implemented in MATLAB programming, and was executed on an Intel dual core™ PC with 3.0-GHz speed and 4 GB RAM. To check the performance of the proposed BFO algorithm, the 69-bus radial distribution feeder system was considered in different test cases.. We studied two test cases with the loads are identical to the values given in [11], ie. The total demands of the 69-bus system are 3802.19 kW and 2694.60 kVAR.. The substation voltage and load power factors in both scenarios were considered as 1.0 p.u. and lagging p.f., respectively.

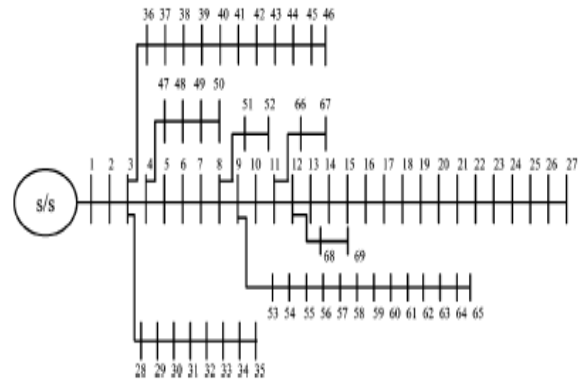


Fig. 3. Single-line diagram of the 69-bus feeder system

Line loss reduction analysis is based on the simple case of an IEEE 69 bus radial distribution feeder [4] is considered with following cases:

- (I) System without DG
  - (II) System with the inclusion of one DG to share full load
  - (iii) System with the inclusion of one DG & one Capacitor to share full load
- Case (I): System without DG

This is a reference scenario, in which no DG unit is connected to the system (default case). The voltage profiles of the feeder system with out DG placement has shown in fig. 4.

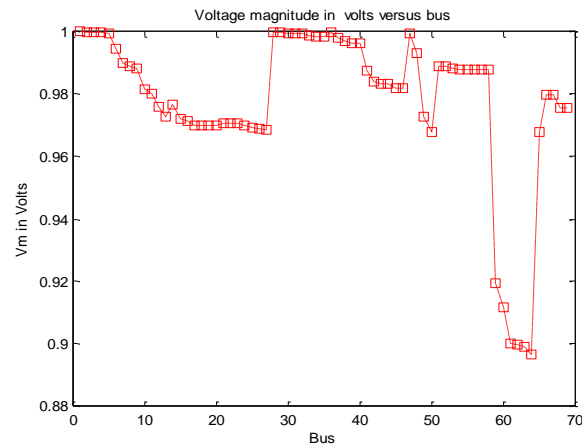


Fig. 4: Voltage magnitude in p.u volts versus bus numbers before DG placement.

It is observed that from bus number 59 to 64 the voltages in p.u are 0.919, 0.912, 0.9, 0.9, 0.899 and 0.897 respectively. These voltages are the lowest among 69 buses.

Table1: Optimized results before DG placement

Particulars	units
Real power ( MW)	3.892
Reactive power (MVAR)	2.802
Active load ( MW)	3.802
Reactive load (MVAR)	2.694
Total real power Loss ( MW)	0.226
Total reactive power loss (MVAR)	0.202

Case 2: System with one DG to share full load

In this, the voltages are improved in all the buses  
 In particular from 59 to 64 shown in Appendix 1.

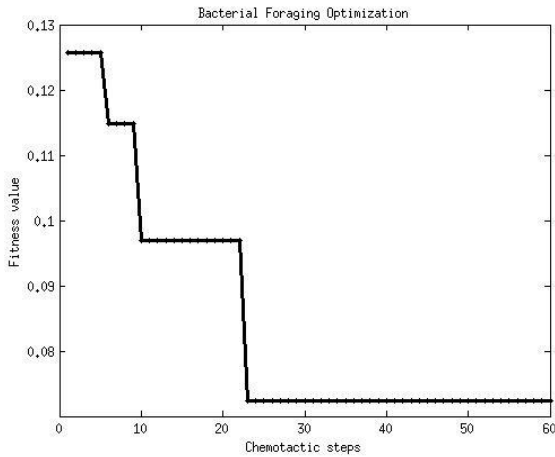


Fig .5: Fitness value versus chemotactic steps for one DG unit connected with actual load

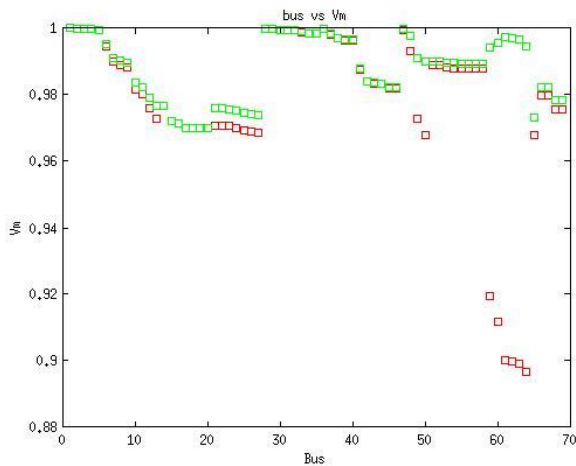


Fig .6: Voltage magnitude in p.u volts versus bus No. after one DG placed to share full load

Table 2: parameters after 1 DG placed to share full load

Particulars	Without DG	With DG
Placement of DG (Bus No)	-	61
value of DG (kVA)	-	1734.8
Voltage in p.u (volts)	-	0.9961
Angle (degrees)	-	-0.1507
Power factor	-	0.9886
Total power Loss ( kW)	226	84.12
%Loss Reduction	-	62.78

Case 3: System with 1DG and one capacitor to share full load

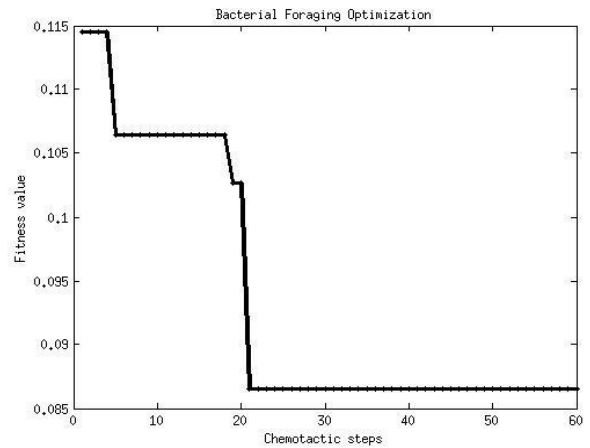


Fig.7: Fitness value versus chemotactic steps for one DG plus one capacitor unit connected with active power supply

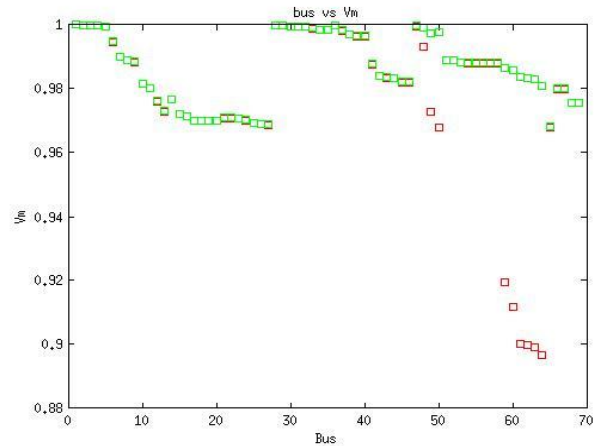


Figure.8: Voltage magnitude in p.u versus bus number for one DG plus one capacitor unit connected to share full load.

Table 4: parameters after one DG unit plus one capacitor is connected with active power supply.

Particulars	With DG
Placement of DG (Bus No)	61
value of DG ( kVA)	1654.8
Placement of Capacitor (Bus No)	50
value of Capacitor (kVAR)	1771
Voltage at DG placed bus in p.u (volts)	0.9977
Angle at DG placed bus in (degrees)	0.3908
Power factor at DG placed bus	0.9245
Voltage at capacitor placed bus in p.u	0.9838
Angle at capacitor placed bus (degrees)	-0.487
P.F at capacitor placed bus (lead)	0.9947
Total power Loss ( kW)	85.4
%Loss Reduction	62.21

### VII.CONCLUSIONS

In this paper, a new population-based BFO has been implemented to solve the mixed integer nonlinear optimization problem. The objective function was to reduce the total system real power loss subject to equality and inequality constraints. Simulations were conducted on the IEEE 69-bus radial distribution feeder systems. The proposed BFO algorithm successfully implemented the optimal solutions at various test cases. The BCO algorithm is simple, easy to implement, and capable of handling complex optimization problems.

Appendix 2: Optimized values after one DG unit is connected to share normal load in 69 bus system using BFO technique

Bus No	Voltage (p.u)	Angle(degrees)	Power factor
1	1	-0.001	0.9999995
2	0.999963062	-0.001827696	0.99999833
3	0.999926124	-0.002655453	0.999996474
4	0.999855678	-0.004949589	0.999987751
5	0.999432299	-0.01106437	0.99993879
6	0.994842983	0.02785304	0.999612129
7	0.990079005	0.068559551	0.997650714
8	0.988978119	0.077936818	0.996964463
9	0.988470617	0.082270981	0.996617651
10	0.981698373	0.203068431	0.979452362
11	0.980216291	0.229815898	0.97370835
12	0.976211313	0.302187767	0.954687674
13	0.973038305	0.359606179	0.936035484
14	0.976556403	0.218740967	0.976171434
15	0.972146218	0.418720309	0.91361
16	0.971332098	0.109703624	0.99398859
17	0.97	0.429546074	0.909154885
18	0.969996457	0.089172913	0.99602673
19	0.96999241	0.073656787	0.997288565
20	0.969989812	0.291364934	0.957852677
21	0.970973705	0.339078857	0.943061455
22	0.970952302	0.339470934	0.94293097
23	0.970718881	0.343725439	0.94150574

24	0.970210821	0.352992258	0.93834247
25	0.969379503	0.368161557	0.932990579
26	0.969036582	0.3744269	0.93071738
27	0.968875267	0.377375947	0.929634752
28	0.999915049	-0.003057645	0.999995325
29	0.999800109	-0.007227664	0.999973881
30	0.999605872	-0.00381987	0.99992704
31	0.999571597	-0.003218224	0.999994822
32	0.999400223	-0.000209374	0.999999978
33	0.998989384	0.006888811	0.999976272
34	0.998451355	0.016278797	0.999867503
35	0.998343243	0.017987214	0.999838234
36	0.999816573	-0.002874332	0.999995869
37	0.998272995	-0.004258298	0.999990933
38	0.99691289	0.021906947	0.999760052
39	0.996520349	0.029476017	0.999565614
40	0.996497915	0.029936174	0.999551946
41	0.987737226	0.222239503	0.975406277
42	0.984018194	0.305185779	0.953791148
43	0.983527399	0.316222083	0.950417047
44	0.983492904	0.320228582	0.949163489
45	0.982120736	0.348132892	0.940011302
46	0.982109566	0.348367352	0.939931292
47	0.999779182	-0.00721671	0.99997396
48	0.997877073	-0.063267456	0.997999282
49	0.992037316	-0.232567382	0.973077881
50	0.991257571	-0.248968181	0.969167182
51	0.988921908	0.078400135	0.996928283
52	0.988906784	0.078690196	0.996905524
53	0.988338615	0.083477341	0.99651779
54	0.988197196	0.084731136	0.996412464
55	0.988102979	0.085561691	0.996341831
56	0.988102979	0.085561691	0.996341831
57	0.988102979	0.085561691	0.996341831
58	0.988102979	0.085561691	0.996341831
59	0.993826375	-0.166536859	0.986164758
60	0.994800171	-0.165735206	0.986297329
61	0.996149963	-0.150750104	0.988658706
62	0.995803655	-0.147762429	0.989102981
63	0.995351824	-0.143867794	0.989668867
64	0.99313746	-0.124769784	0.992226343
65	0.968048854	0.385011974	0.926793936
66	0.980126182	0.231623866	0.973294907
67	0.980125133	0.231645278	0.973289991
68	0.975686721	0.311746083	0.951799461
69	0.975685044	0.311775695	0.951790378

Appendix 2: Optimized values after one DG and one capacitor connected to share full load in 69 bus system using BFO technique

Bus No	Voltage (p.u)	Angle(degrees)	Power factor
1	1	-0.001	0.9999995
2	0.999964995	-0.001740283	0.99999848
3	0.99992999	-0.002480619	0.99999692
4	0.999865349	-0.004512547	0.99998981
5	0.999518468	-0.014211835	0.99989901
6	0.995425256	-0.028577277	0.99959169
7	0.991177444	-0.043860235	0.99903829
8	0.99020142	-0.048105159	0.99884317
9	0.989760495	-0.051064597	0.99869648
10	0.98371427	-0.052704446	0.99861144

11	0.98239746	-0.054173249	0.99853298
12	0.979015595	-0.0894759	0.99599970
13	0.976736348	-0.188703683	0.98224823
14	0.976557155	0.474460183	0.88953947
15	0.972146476	0.365552354	0.93392645
16	0.971332267	0.081474304	0.99668280
17	0.97	0.481418947	0.88633879
18	0.969996457	0.453698589	0.89883218
19	0.96999241	0.283626498	0.96004691
20	0.969989812	0.165374228	0.98635681
21	0.97597783	-0.285118361	0.95962836
22	0.975956537	-0.284730295	0.95973744
23	0.975724318	-0.280519328	0.96091178
24	0.975218876	-0.271347412	0.96341062
25	0.974391844	-0.256333687	0.96732601
26	0.974050692	-0.250132677	0.96887958
27	0.973890208	-0.24721393	0.96959794
28	0.999918916	-0.002882808	0.99999584
29	0.999803976	-0.007052794	0.99997512
30	0.99960974	-0.003645027	0.99999335
31	0.999575465	-0.003043385	0.99995369
32	0.999404092	-3.46E-005	0.99999999
33	0.998993255	0.007063571	0.99997505
34	0.998455228	0.016453484	0.99986464
35	0.998347116	0.018161888	0.99983507
36	0.999820425	-0.002699202	0.99999635
37	0.998276633	-0.004078863	0.99999168
38	0.996916356	0.022093903	0.99975594
39	0.996523767	0.02966515	0.99956002
40	0.99650133	0.030125435	0.99954626
41	0.987739455	0.222481569	0.97535289
42	0.984019919	0.305450745	0.9537115
43	0.983529058	0.316490097	0.95033366
44	0.983494561	0.320497306	0.94907886
45	0.982122203	0.348409708	0.93991683
46	0.982111032	0.348644235	0.93983673
47	0.999780582	-0.005690748	0.99998380
48	0.997674269	-0.034617581	0.99940087
49	0.991134994	-0.110916198	0.99385510
50	0.990156675	-0.100719798	0.99493204
51	0.990145279	-0.047642986	0.99886528
52	0.990130174	-0.047353642	0.99887902
53	0.989628665	-0.04986138	0.99875717
54	0.989487431	-0.048610852	0.99881872
55	0.989393337	-0.047782462	0.99885863
56	0.989393337	-0.047782462	0.99885863
57	0.989393337	-0.047782462	0.99885863
58	0.989393337	-0.047782462	0.99885863
59	0.99433958	0.26457186	0.96520454
60	0.995752254	0.312542175	0.95155498
61	0.997510741	0.399094494	0.92141323
62	0.997164908	0.40207402	0.92025135
63	0.996713696	0.405958024	0.91872449
64	0.994502371	0.425003764	0.91103718
65	0.973068058	-0.239656408	0.97141959
66	0.98230755	-0.052373302	0.99628832
67	0.982306504	-0.052351985	0.99862994
68	0.978492507	-0.079972292	0.99680392
69	0.978490835	-0.07994284	0.996806272

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