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Distribution System's Loss Reduction by Optimal Allocation and Sizing of Distributed Generation via Artificial Bee Colony Algorithm

Shivaleela Kori, Shivakumara Swamy R, Dr. V Venkatesh, Chandrashekar Badachi

PG Student,Dept of EEE, AIT,Bangalore-107
Assit.Prof,Dept of EEE, AIT,Bangalore-107
Principal, Dept of ECE, CIT,Gubbi,Tumkur-572216
Asst.Prof, Dept of EEE, AIT,Bangalore-107

Abstract: - Distributed generation (DG) refers to generation applied at the distribution level. It offers a valuable alternative to traditional sources of electric power for industrial, residential and commercial applications, particularly where transmission and distribution costs are high. Great attention should be rendered to the problem of allocation and sizing of DG. The installation of DG units at non optimal places can result in an increase in system losses, implying in an increase in costs and therefore, having an effect opposite to the desired. An Algorithm proposed in this paper is Artificial Bee Colony (ABC). This method helps in optimal allocation and sizing of DG's in order to minimize the total system real power loss.

Keywords: - *ABC Algorithm,Distribution System, DG sizing, DG allocation,Distributed Generation,Loss reduction.*

I. INTRODUCTION

If a utility needs generation anywhere it can get it, the utility or end users can quickly install distributed generation. Applying generation closer to the load benefits the transmission and distribution infrastructure. Local generation can relieve overburdened transmission and distribution facilities as well as reduce losses and voltage drop. DG offers a valuable alternative to traditional sources of electric power for industrial, residential and commercial applications. The impact of DG in system operating characteristics, such as electric losses, voltage profile, reliability, among other need to be appropriately evaluated [1]. A new methodology to optimize the size and location of DG based on the level of power loss reduction has been developed[4].[5] Based on the active and reactive power injection of DG and voltage sensitivity of lines, the optimal operating condition of DG to support voltage in a distribution system was developed . Analytical techniques have been developed by considering constant impedance and constant load models, separately to obtain optimal DG size [6].Minimization of active and reactive power generation costs and DG location, by using Genetic Algorithm (GA), and optimal power flow calculation [7]. In order to minimize the load supply cost the evolutionary programming has been used as optimization technique [8]. Based on the exact loss formula, the analytical expression were used to optimally allocate and DG sizing by minimizing the total power loss in primary distribution system[9].Power flow for radial distribution feeders by considering embedded distribution generation sources and shunt capacitors[10].

Many optimization techniques have been used and discussed in literatures. DG has advantages like power loss reduction, environmental friendliness, and voltage improvement, postponement of system upgrading, and increasing reliability. Genetic Algorithm (GA) has been used only for sitting, sizing has been done by Optimal Power Flow (OPF).The nature inspired known as Swarm intelligence focused on insect behavior in order to develop some meta-heuristics which can mimic insect's problem solving abilities. A new optimization approach that employs an artificial bee colony (ABC) algorithm to determine the optimal DG-unit's size, power factor, and location in order to minimize the total system real power loss. The ABC algorithm is a new metaheuristic, population-based optimization technique inspired by the intelligent foraging behavior of the honeybee swarm. This algorithm makes the programming simpler.

II. PROPOSED METHOD

A).Problem statement:

The objective function is to minimize the total system real power loss:

Objective Function = $$min \sum_{i=0}^{n} \left(\frac{P_i^2+Q_i^2}{V_i^2}\right) * r_{i+1}$$

Where:

P_i = Real power flows from bus i to bus i + 1.

Q_i = Reactive power flows from bus i to i + 1.

V_i = Bus voltage at bus i.

r_{i+1} = Resistance of line connecting buses I and i+1

The equality constraints are the three nonlinear recursive power-flow equations describing the system:

$$P_i - \frac{r_{i+1}(P_i^2+Q_i^2)}{V_i^2} - P_{L_{i+1}} + \mu_P AP_{i+1} - P_{i+1} = 0$$

$$Q_i - \frac{x_{i+1}(P_i^2+Q_i^2)}{V_i^2} - Q_{L_{i+1}} + \mu_Q RP_{i+1} - Q_{i+1} = 0$$

$$V_{i+1}^2 = V_i^2 - 2(r_{i+1}P_i + x_{i+1}Q_i) + \left(\frac{(r_{i+1}^2+x_{i+1}^2)(P_i^2+Q_i^2)}{V_i^2}\right)$$

Where i= 0,1,2,3,….n

The inequality constraints are:

$$|V_{min}^{spec}| \le |V_i^{sys}| \le |V_{max}^{spec}|$$

$$S_{i,i+1}^{sys} \le S_{i,i+1}^{rated} \ge S_{i+1,i}^{sys}$$

$$S_{max}^{DG} \ge S_i^{DG} \ge S_{min}^{DG}$$

$$p.f._{max}^{DG} \ge p.f._i^{DG} \ge p.f._{min}^{DG}$$

B).Load Flow Study:

The single line diagram of IEEE 69 bus feeder system and load flow graph for 69 bus system is as below in figure(1) & (2) respectively. The bus voltage should be from 0.95 to 1.05 volt per-unit. From the graph it is clear that there is a drop in voltage below 0.95 between the bus 60 to 69 bus. Thus it is clear that the allocation of distributed generation is in between these buses in the distribution generation. The optimal sizing and allocation of DG in distribution system will be using Artificial Bee Colony Algorithm.

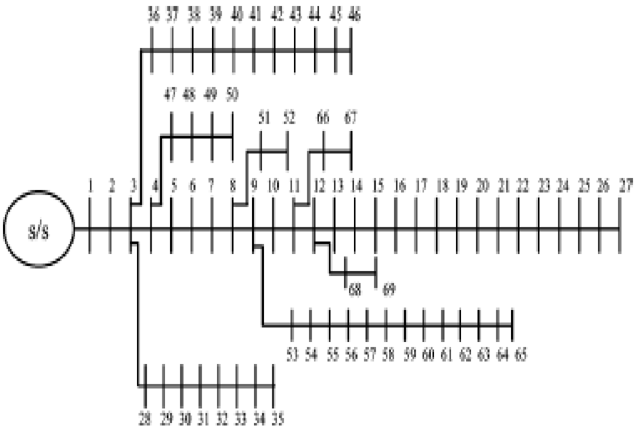


Fig: 1. Single Line Diagram of 69 bus feeder system.

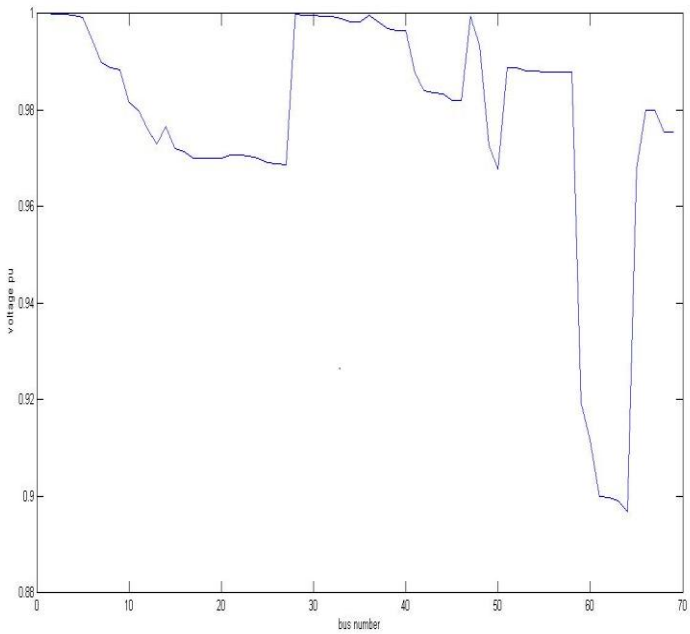


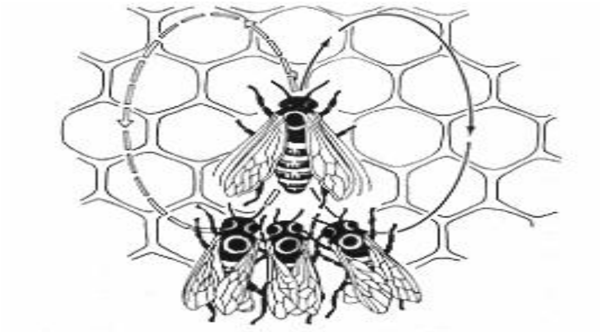
Fig: 2. Load Flow Graph of NR-Method for 69-Radial bus system

Load-Flow Results:

NR LF	Active Power(MW)	Reactive Power (Mvar)
Load	3.802	2.694
Generation	3.892	2.802
Line Losses	0.225	0.202

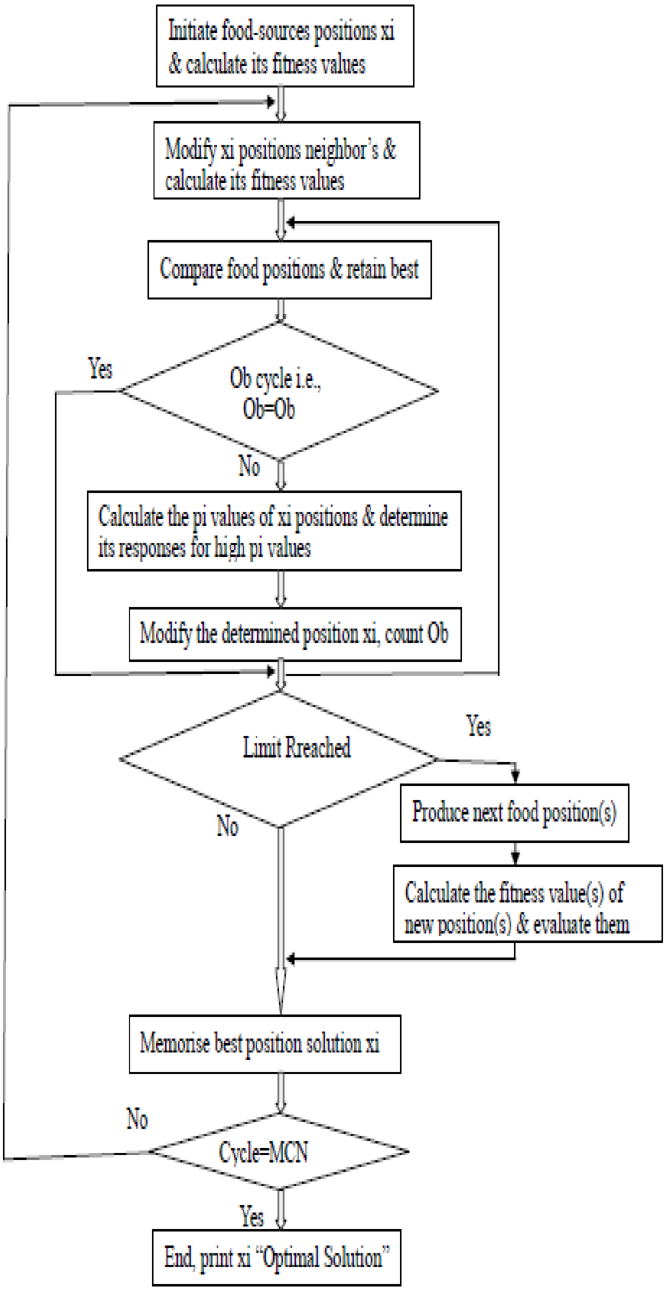
C) ABC Algorithm:

Artificial Bee Colony (ABC) is a relatively new member of swarm intelligence. ABC tries to model natural behavior of real honey bees in food foraging. The information exchange among individual insects is the most important part of the collective knowledge. Communication among bees about the quality of food sources is being achieved in the dancing area by performing waggle dance. Bee system consists of two essential components: Food Sources and Foragers.



Fig(3): Waggle dance of honey bees

The figure below shows the flow-chart of ABC Algorithm.



III. RESULTS AND DISCUSSION

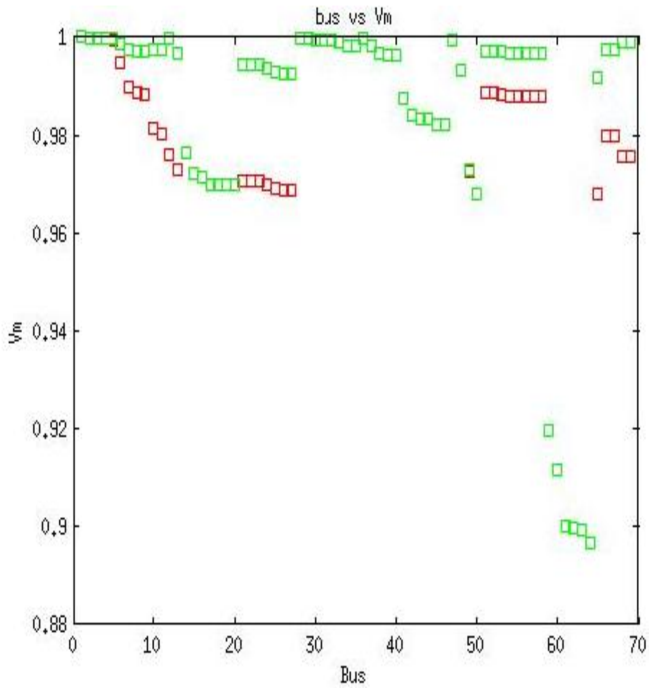
A 69-radial distribution feeder system has considered for different test cases. Two load scenario's scenario-I for Normal load and Scenario-II for 50% extra of normal load, all the three test cases conducted. Test case-1 is with one DG and Test case-2 with 2 DG. Test case-3 with 1 DG and 1 Capacitor. The results are as tabulated below in table (1), and (2).

Senario-I(For Normal Load)			
Test Cases	**Active power losses**	**DG & Capacitor Placed at Bus no**	**% Reduction of Losses**
1). 1 DG	0.08816	61	39
2). 2 DG	0.06739	61 and 12	29
3). 1 DG and 1 Capacitor	0.08252	61 and 04	36

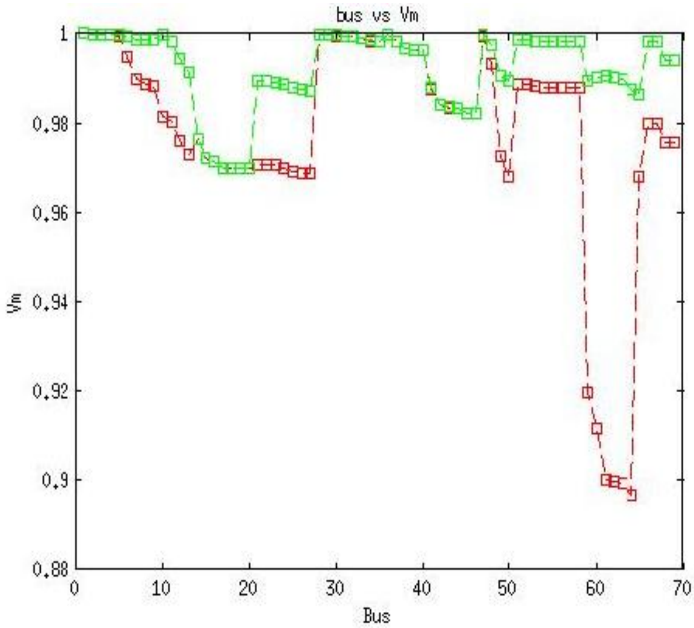
Table: (1) Results for 69-bus feeder systems Using ABC Algorithm

Senario-II(50% Extra of Normal Load)			
Test Cases	**Active power losses**	**DG & Capacitor Placed at Bus no**	**% Reduction of Losses**
1). 1 DG	0.11695	61	51
2). 2 DG	0.09007	61 and 09	40
3). 1 DG and 1 Capacitor	0.11502	61 and 09	51

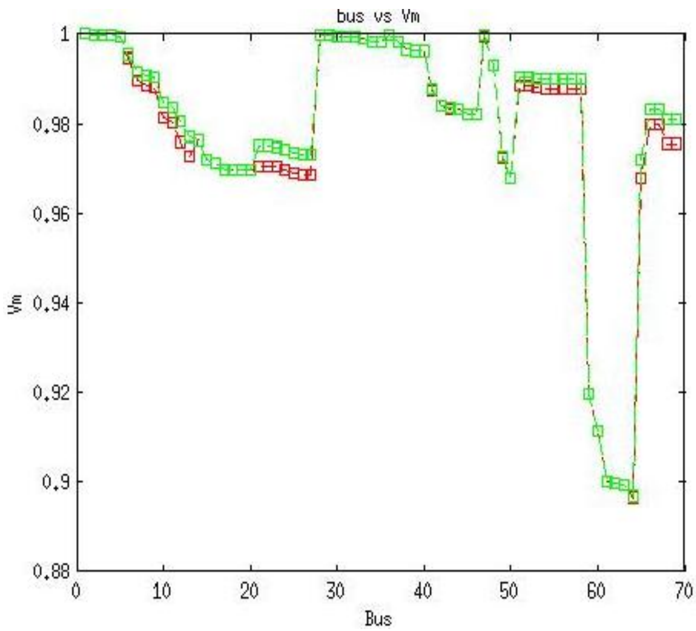
Table:(2) Results for 69-bus feeder systems Using ABC Algorithm



Fig(4): Voltage Profile of 69-bus system for Load Senario-1 for 1 DG



Fig(5):Voltage Profile of 69-bus system for Load Senario-1 for 2 DG



Fig(6): Voltage Profile of 69-bus system for Load Senario-1 for 1 DG and 1 capacitor.

The above figures(4), (5) and (6) shows the voltage profiles of the 69-bus system for different test cases of load Senario-1. The red colour is the default voltage profile, while the green colour shows the enhancement of voltage profile by ABC algorithm. The similar graphs are found for remaining test case-2 and test case-3. The results for all test cases are tabulated as in table-1 and table-2 for scenario-I and scenario-II respectively.

IV. CONCLUSION

The new population based ABC algorithm has been proposed to solve the mixed integer nonlinear optimization problem. The objective function function was to to reduce the real power loss subjected to equality and inequality constraints. The simulation was conducted on 69-bus radial distribution feeder system and the proposed ABC algorithm has successfully achieved the optimal solutions at various test cases. The graphs shows that the test case-2 with 2 DG the loss reduction is more and the voltage profile has also improved.

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